SCIENTIFIC ILLUSTRATION

Meadowlark and nest (4-color reproduction)

SCIENTIFIC ILLUSTRATION

By

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PREFACE

This book is primarily intended to aid students of science and others engaged in the preparation of manuscripts that require illustrations. While it is not a manual of freehand drawing, much of its matter relates to more advanced preparation, including well-recognized and effective methods of procedure in producing finished illustrations. It is also intended as a textbook for use in the study of scientific illustration, upon which subject the present literature is not extensive.

Because of the writer's long experience in this special field, the preparation of this book was undertaken with the hope that it might supply needed information covering many of the essential details of scientific book illustration. With that end in view, and for the sake of completeness, it was found necessary to cover such obvious topics as "Purpose and Advantages of Illustrations," and other general matter. Regardless of the simplicity of treatment, the aim has been to point out effective methods of preparation and the proper fitting, assembling, and display of illustrations designed for scientific publications, and to place the matter in form convenient for reference.

To be able to supplement descriptive matter by a sketch here and there, or by a drawing of some object, is an obvious advantage. But the ability to draw an authentic and adequate picture is no more important or essential than a knowledge of many other technical details connected with the specialized art of scientific book illustration. This tendency to specialize is shown in the field of science, since many investigators prefer to develop a more profound knowledge of one branch rather than a detailed familiarity with the major subject. Thus in the matter of illustrations, which are an important corollary to the literature of science, their very character, purpose, and treatment place them in a class quite distinct from the more

popular application of the art. It is from this standpoint that the subject of scientific illustration has been treated in the following pages.

The lack of effectiveness shown in the illustrations in many scientific books and pamphlets, and their complete inadequacy in some cases, is often apparent; while in others they are found to have been carefully and artistically prepared. Such variation may be seen by even a casual examination. Thus it happens that many good scientific presentations lose much of their deserved effectiveness because of the poorly planned and poorly executed illustrations which have been included. The tendency in such cases is to cheapen the written contents of an otherwise patiently developed and well-presented thesis. It is therefore surprising to find crudely prepared illustrations incorporated in any serious book. With the thought not only of helping the scientific writer to select and plan his illustrations but also of aiding the artist whom he may employ, the suggestions in the following pages are offered.

In 1920, the United States Geological Survey published* a paper on illustrations prepared by the present writer which was intended only for internal office use. Since geology and kindred subjects formed the basis of that paper, some of the matter has necessarily been incorporated here, but only as one of the sciences to which these pages are dedicated. My thanks are due the Director of the Geological Survey for permission to use this matter and some of the illustrations which accompanied it, in addition to those prepared especially for the present work.

The brief descriptions of engraving processes and other forms of reproduction of illustrations are also included as an aid in determining the process most appropriate to the kind of drawing to be reproduced and the quality of reproduction that may be expected. Some knowledge of these processes will tend toward better discrimination in the matter of expense.

This book does not recognize modernistic tendencies in the display and technique of scientific illustrations. It attempts to

* John L. Ridgway, *The Preparation of Illustrations for Reports of the United States Geological Survey, with Brief Descriptions of Processes of Reproduction*, Government Printing Office, Washington, D.C., 1920.

adhere to the classic, which fortunately is still the dominant, character in scientific publications. It describes methods of procedure that have developed from the early 'eighties to the present time, and represents up-to-date practice in maintaining correct standards.

This manuscript would not be complete without an expression of gratitude to certain friends who have offered helpful advice or words of encouragement: William Alanson Bryan, who first suggested the work; Chester Stock, for facilities offered at the California Institute of Technology; and Eustace L. Furlong, Harry Harris, John H. Maxson, Willis P. Popenoe, George Austin Schroter, G. E. MacGinitie, Ralph D. Reed, and Mrs. D. D. Hughes.

J. L. R.

PASADENA, CALIFORNIA
December 1, 1937

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§1. Purpose and Advantages of Illustrations

In no period of the world's history have illustrations been so profusely used as they are today in the many books and magazines of popular interest and in the great flood of advertising matter that is gratuitously distributed from day to day. Real art, including commercial art—some of which is the work of acknowledged modern masters—has become almost commonplace. The writer has seen this develop from the time when the pages of magazines and books of all kinds were illustrated only with woodcuts, some beautifully engraved, others lacking artistic merit. The reason for this tremendous advance in the use of illustrations, whether for embellishment or simply as a means of advertising, is that they attract attention and promote greater interest. Publishers and business men know that the picture attracts, sometimes even more than the printed matter that goes with it, and they are glad to pay the additional cost of providing it.

No similar development has taken place in the literature of science; but the same truth holds there—that illustrations lend interest, aid in the elucidation of facts, save much valuable time in writing descriptive matter, and relieve the reader of much mental effort by giving him a clearer and easier conception of what he reads.

It would be impossible to present a clear understanding of the physical characteristics of a bird or other creature based alone on measurements, color, and the usual diagnostic characters, or to describe adequately the form and details of many organisms, without illustrations. Both the writer and the reader would be burdened with undue descriptive matter. Illustrations, if properly prepared, relieve that condition.

Another real advantage is shown in the use of illustrations that display photographic reality. Such illustrations make the text less open to dispute and thus serve the double purpose of depiction and corroboration.

The real advantage of illustrations is so generally well known by all scientific writers that extended comment is not necessary. The seeming lack of progress, however, in the use of illustrations for scientific purposes compared with the abundance of those now used in all other kinds of literature perhaps indicates that scientific authors should give greater consideration to the inherent value and subservient character of good illustrations.

§2. Kinds of Illustrations

The smaller illustrations, those printed with the type matter, are usually designated as text cuts, a term derived from the fact that all such illustrations were originally engraved on wood, the resulting block being known as a "woodcut" or simply a "cut." A plate, as distinguished from a text figure (or cut) is generally a more elaborate illustration, though not necessarily so, and is so called because in the early days, long before the half-tone process came into general use, many of the larger illustrations were engraved by hand and printed from metal plates. The resulting prints thus became known as "plates," a term now generally applied to all full-page illustrations in scientific papers and books which are printed separately and inserted.

A plate may not differ essentially from a text figure in point of value as an illustration or in pictorial effect, but plates are generally more elaborate and larger, and the fact that they require more space is often the deciding factor in their use.

Figures have a direct and close connection with the text, while plates may have only a general bearing on the subject matter, as for example a scene showing the general character of a region under discussion. They may also show great detail as discussed in the text, from which the reader is referred back to the plate.

In addition to plates as distinct from figures, as these terms

are generally used, there are several kinds of illustrations in common use. These may be classified in a general way as follows: finished drawings, photographs, sections, graphs or curves, plans, figures of apparatus, stereograms, and maps. Among these some may be so prepared and be so important as to possess permanent value; for example, illustrations which do not lose value through lapse of time or by gradual alteration of data, such as well-prepared drawings or photographs of specimens, photographs or drawings of natural phenomena, detailed maps, good drawings of block diagrams and sections, and many others. Others may be called ephemeral; for example, maps showing progressive stages, key maps, and curves showing yearly production. Ephemeral drawings should be prepared in such a way as to minimize cost and be reproduced by inexpensive processes. This principle of degree of permanence should receive first consideration from the scientist and his illustrator.

§3. Plates and Figures

As already stated, plates generally require special treatment and are usually printed separately and inserted, while text figures are blocked in their place with the type matter or text and do not therefore require separate printing; but (if text is printed by letterpress) they must be reproduced (engraved) by what is termed a relief process which gives them a printing surface like type (see §59). However, in some publications the use of a coated or supercalendered paper permits the printing of half-tone cuts as text figures; in fact, by the use of supercoated paper so-called plates of fine-screen half-tones also can be printed with the text, and a separate printing is not always necessary. But coated paper for the text is not desirable, except, as stated, to facilitate or to permit the printing of half-tone illustrations.

Subdivisions of plates and figures.—For convenience of reference plates and figures should be designated in contrasting fashion. The approved practice is to assign Roman numerals to plates and Arabic numerals to figures. Moreover, if a plate consists of two or more distinct parts (photographs or draw-

ings), the latter having been made separately, each part should be marked with a capital letter—A, B, C, etc.—which should be placed, when practical, directly under each part. If it is made up of many parts, as, for example, plates that accompany papers on paleontology, each part should be similarly marked with a small Arabic numeral—1, 2, 3, etc.

If a text figure is subdivided into two or more parts, each part should be marked with an italic capital—*A, B, C,* etc. And if details of a part are to be described each detail should be marked by an italic lower-case letter—*a, b, c,* etc.

These rules may seem to be arbitrary, but they are logical. For example, in the details of a text figure, it is a better citation to refer to "Figure 5, *a, b, c,*" than to "Figure 5, *1, 2, 3,* etc."

§4. Sizes of Illustrations

Scientific books are of such varied sizes that illustrations can rarely be arranged before a manuscript has been submitted and the form of publication has been decided upon; for *the size of the text page must determine the size of the illustrations.* (This is particularly true in applying the several sizes in the following tables.)

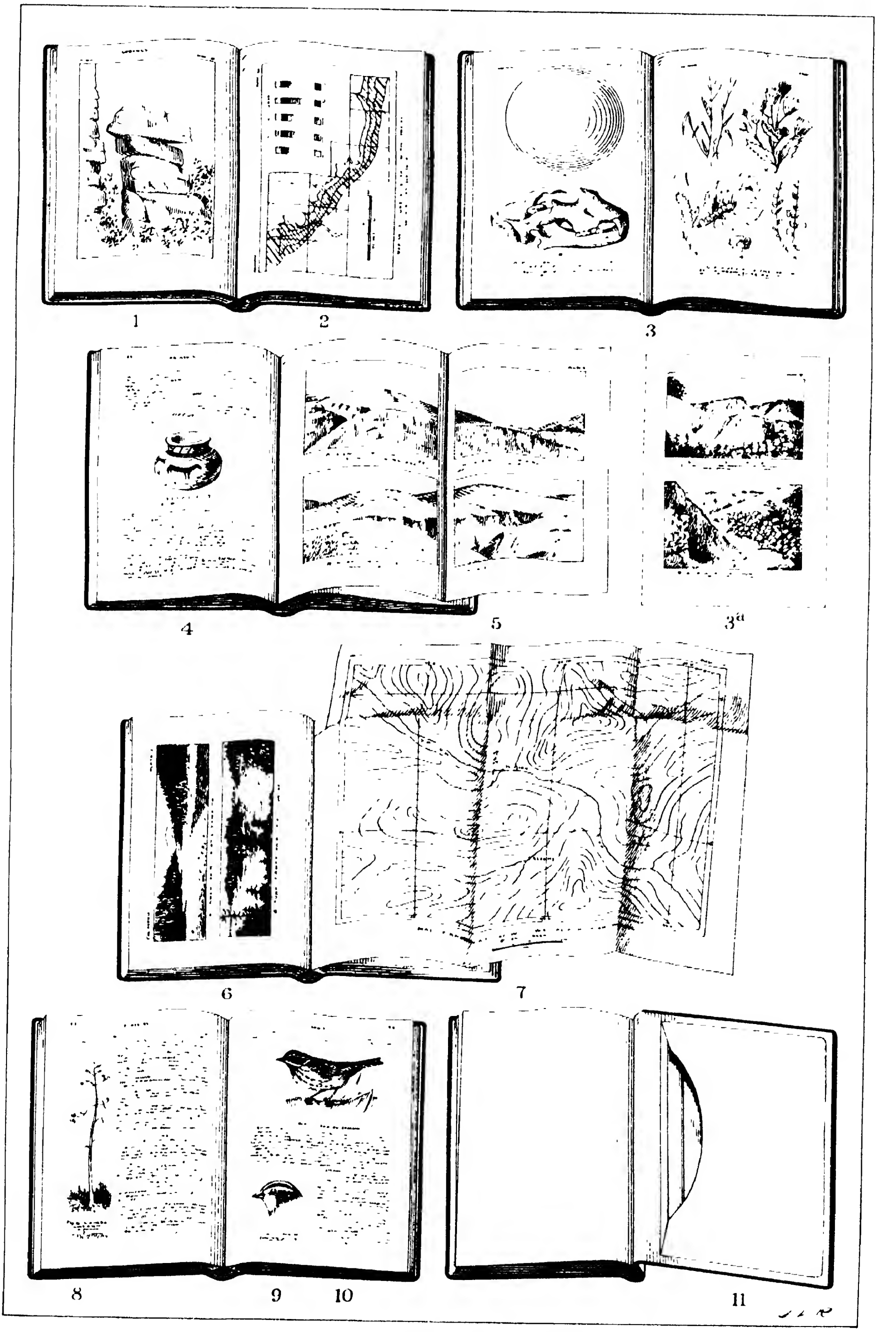
The sizes of the serial publications in which scientific papers are most commonly used, however, are those known as octavo and quarto. These terms originated in the use of large sheets of paper which were so folded as to make eight printed pages for the octavo (sometimes written 8vo) and four pages for a quarto (or 4to). Other sizes are traditionally referred to as Crown, Demy, Imperial, Medium, Royal, etc.

The sizes of the pages for both octavo and quarto volumes vary somewhat but are often of the sizes given in the following table, which also gives the size of the printed text in inches:

Format	Dimensions: Paper	Dimensions: Text or Illustration
Octavo (maximum)	6½" × 9½"	4⅜" × 7¼"
Quarto (maximum)	9¼" × 11½"	6" × 8½"

The limiting dimensions of plates and figures, in inches, are given in the following table. If for any reason a plate can-

PLATE I



Methods of inserting plates and figures

Nos. 1, 2, 3, 3a, 5, 6, and 7, plates; Nos. 4, 8, 9, 10, text figures; No. 11, pocket.

not be reduced to the dimensions of a single page, the illustration can be made to fold once or more; but this is not often desirable. If large and unwieldy, as in the case of large maps, the illustration may be placed loose inside or be folded in a pocket inside the back cover, as shown in Plate I.

Format	Dimensions: Single-page Plate	Plate with One Fold	Text Figure
Octavo (maximum)..	4½″ × 7¼″	7¼″ × 9″	4⅜″ × 7¼″
Quarto (maximum)..	6½″ × 8½″	8½″ × 12″	6″ × 8¼″

For an octavo book a single-page plate with side title should be less than the normal width as stated in the table, in order to accommodate the title, four inches being the usual width. Likewise, the quarto plate should be correspondingly narrower. If the title consists of several lines, the upright plate (title below) should also be of lesser depth.

§5. Selection of Appropriate Illustrative Material

During the preparation of a manuscript, a feature or subject needing further elucidation or that will be aided in clearness by some kind of pictorial expression generally makes its appeal to the author at that time; and there is sometimes difficulty in selecting material from which the needed illustrations can be evolved whether from photographs or by drawing. If, for example, a photograph is selected, its adoption as an illustration does not always depend upon its superior quality as a photograph. Its illustrative value in showing the points that are essential to the illustration is of first importance, notwithstanding the fact that it may not reproduce well. The implication here is that, while a photograph may not be a good one, if it shows what is desired it can by proper manipulation be made to serve its purpose and may, furthermore, be transformed into a creditable picture, as described in §22. Unfortunately, poor photographs are often used without first having been carefully retouched, and thus fail to serve any useful purpose.

Usually the greatest problem in selecting illustrative material concerns obtaining suitable drawings. Since drawings must be made either by the author or by someone employed to make them, it is quite necessary that the person so employed have something to build upon. The foundation for such drawings must, therefore, be furnished by the author. His sketches may be crude, but if they show in some way the essential points for which they are intended they will suffice.

Usually no great difficulty will be encountered in securing the services of a competent artist. Many proficient draftsmen and professional illustrators, however, are not familiar with the details of scientific book illustration and it is one of the purposes of this book to suggest correct methods of carrying on such work, since scientific illustrating differs perceptibly from the usual methods pursued in drafting and in popular illustrating work.

Since to procure good drawings adds an expense to the author that is not returnable—particularly if used as illustrations in many publications in which short papers are accepted —an author is often forced to submit what he can and with as little expense as possible. Yet as each of these papers will become of value to successive writers, the question might well be regularly asked whether or not the illustrations should be so prepared that they will represent the best that can be procured and thus add greater interest to the paper as well as bring additional credit to the author.

In selecting prints it should be known that a good photograph will show some detail in the shadows and full detail in the middle tones. It will be evenly toned throughout and will be free from accidental and photographic blemishes. But these requisites are not always sufficient to warrant its use if it does not show the essence of a needed illustration. It should be of superior scientific interest to begin with; if not, it should be abandoned and not necessarily replaced by another print unless the new print shows what is needed.

As the half-tone process is most often used for reproducing plates, it should be remembered that in this process there are

several varieties of finish entailing a difference in cost dependent upon the amount of hand work required. They consist of: (1) plain square-trimmed cuts, (2) routed or blocked-out cuts, and (3) vignetted and tooled cuts. These are named in the order of their relative cost, the first being the cheapest.

When the matter of expense must be considered, a choice of the method that will produce a satisfactory result with least cost may be advisable.

In square-trimmed cuts the half-tone tint remains over the picture and its background. That is, if the illustration submitted is a drawing on white paper, a penciled rectangle should indicate the limit of the tint. In cuts of this kind another saving in expense can be effected by placing the number, or other lettering, inside the rectangle; it will then become part of the half-tone plate. Otherwise the number or other matter would need a separate negative or have to be *tooled* into shape.

Where it is desired that the cut appear on a white ground, the engraver must rout or block out the ground tint. When vignetting is required the necessary tooling also adds to the expense.

Some publishers require that all half-tones be "square-trimmed" and that the numbers or other lettering, if needed, be so indicated that it will be reproduced as a part of the half-tone cut. For example, see Plate VII.

Any photograph that needs much retouching should be larger than publication size, so that the retouching — brush marks, penciling, etc.—may be softened by reduction. For slight retouching they need not be larger. A photograph that is to be enlarged in the process of reproduction must be sharp in detail and show no previous retouching.

Unmounted prints are always preferable for use in making illustrations. When two photographs are to form a single plate each should be numbered in pencil and placed in an envelope bearing the number of the plate and its title. The plate should then be represented by a dummy, showing the position of the photographs and their reproduced size. The envelope will protect the prints and keep them together, and the numbers will

identify them. Red ink should not be used to mark photographs, as it reproduces and cannot be erased. No marks should be made in any part to be reproduced, not even with pencil on the back of a thin print, for the impression may photograph as a shadow.

Two photographs can generally be combined as a single-page plate, as shown in Plate I, and with some trimming and reduction three photographs measuring approximately $3\frac{1}{4} \times 5\frac{1}{2}$ inches may be placed one above the other to form a full-page octavo plate. Four photographs in which the longer dimensions represent vertical distances may sometimes be used when placed sidewise on the page, provided they will bear reduction.

Since photographic reduction usually involves some loss of detail, reduction to proper size may also be accomplished by trimming. The extent of such trimming as it can bear without sacrificing essential parts may always be indicated on the back of a print, on a temporary mount or margin, or by a statement, such as "one inch may be cut off on right," "one-half inch on left," or "two inches at bottom." *A line should never be drawn across the face of a photograph* to mark such trimming, as it cannot be erased.

In trimming photographs for reduction to a given size and proportion, the diagonal rule is indispensable: First, draw on a piece of paper a rectangle representing the exact outline needed for the picture or plate when reduced. Then draw a diagonal line from the lower left corner to the upper right corner of the rectangle, extending the line beyond. Any point on the diagonal line beyond the rectangle will represent the upper right corner of the new picture and will indicate the amount of trimming necessary to give it the required proportions when reduced.

When there are a number of illustrations for one publication, the diagram just mentioned can be made on a sheet of tracing cloth or celluloid and can be laid over each picture. This method makes it unnecessary to figure the reduction even by the simple rules of proportion.

When a series of drawings or photographs bear different re-

ductions or enlargements, and it is desired to reproduce each one to a uniform scale, the following method has been found to be simple and accurate. Reductions ordinarily are represented by fractions in this order—1/5, 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, and 4/5:

Draw a line on an ordinary sheet of paper for each figure to represent its present length and fractional scale. Enlarge or reduce this line with dividers to natural scale and then point off on this line the fraction to which it is to be reproduced, in each case.

For example, a photograph is 2/3 natural size. Draw a line the length of the photograph which is to be reproduced to 1/2 natural size. Increase the length of the line one-half, then from this increased total length of the line (which will represent natural size) check off one-half to which the photograph is to be reproduced.

Should the scale of the photograph or drawing be 7/8 natural size (or other fraction) add, in this case, one-eighth to the length of the line to represent full size and then check off the reduction.

In this way a plate or group can be made up giving each figure a uniform reduction and, if the plate is found to be too large for the book, a fractional reduction can be marked, thus keeping all the figures in their same relative scale.

This method is of particular value when published figures are to be redrawn to fit into a new plate or group in which a uniform scale for each figure is desirable.

An author's first concern about a photograph is naturally as to whether or not it has in it the essentials of an illustration. It may have these and yet not make a satisfactory illustration. If it is an outdoor scene, he is apt to see more in it than the reader. Certain details of importance may be only faintly shown, yet he knows they are there, and he readily overlooks the fact that the reader will not be equally well informed. Sometimes an important part of a scene may thus be partially hidden or almost lost in hazy distance. Therefore, it is sometimes a disappointment to find illustrations that lack definition or that fail to show what was intended only through lack of better selection, better shaping, and better craftsmanship.

Economy in selection.—The effort to economize in illustrations should naturally begin at the inception of each one or when it is realized that the illustration is needed. The amount of saving will then depend upon the character of the drawing to be made or the quality of the photograph to be selected. If an original field sketch or indoor drawing is very poorly prepared, it will need redrawing by an expert; and this involves expense. If the photograph is not of a quality suitable for reproduction, it will require expert retouching. These are both factors that affect cost at the beginning.

Next comes the matter of size. The cost of all photoengravings is rated on a square-inch basis. For letterpress printing zinc etchings (line cuts) are cheapest. Half-tones are more expensive, but their cost (as already stated) depends also upon the kind of finish. Photolithographs are usually larger and must be printed by the lithographer; thus their increased size and the items of paper and printing increase their cost. Photogelatin plates—heliotype and similar processes as well as photogravure—are very expensive compared with the two processes first named. And colored reproductions by any process are most expensive.

Therefore, numerous considerations figure in an endeavor to economize, and if economy is all-important it can be more easily effected by starting right and by choosing to utilize relatively inexpensive methods. Considerations of economy should not wait until the end, that is, after the illustrations have been prepared.

Number of illustrations allowed.—No rule has been found limiting the number of illustrations allowable in a publication, but as the need for illustrations varies from paper to paper the number of pages in a manuscript is always a deciding factor.

Drawings or figures made in pen and ink that are closely tied in with the text, or that express an author's deductions, are rarely in excess of the needs of a paper. But the number of photographs submitted is often excessive, and in their selection an author may easily fall into the error of over-illustration. The number of illustrations is also a matter depending on agree-

ment between author and publisher, in which cost of reproduction is another deciding factor.

§6. Photographs as Illustrations

Notwithstanding all that is said in these pages concerning drawing, many good scientific illustrations are in one way or another derived from photographs. They are more easily obtained than drawings, they can be skillfully retouched, and they may often be translated into good pen or brush drawings (see §20). There are, however, some kinds of drawings that cannot be replaced entirely by photography, including a great variety of subjects, among them minute forms in which certain parts can be studied and interpreted only by a change of focal plane, and also restorations or life-like drawings of living and extinct forms of life (see §18). Hence with the substitution of photographs for many kinds of drawings there is yet much for the pen-and-brush artist to do.

Photography is an art in which there are so many details that an error at any one step in the process generally results in failure. Much success is gained by experience, but an understanding of optical principles, films, lenses, printing papers, developers, and many other details is always an added assurance of successful operation.

As covering the subject of photography in its various phases and uses in scientific illustration, including its application to or connection with the microscope, the paper entitled *Principles of Micropaleontology* by Hubert G. Schenck, of Stanford University, is highly recommended.

Essential features of a photograph.—Photographs are the cheapest original illustrations. Compared with good pen drawings, however, their reproduction, usually by half-tone or one of the flat-bed processes, involves more expense, since they cost more than line cuts. Then again, whereas it has been said that photographs do not lie, on the contrary they are often found to give false or widely misleading effects. This is often true in photographs of specimens when, in addition to the normal illumination, a strong reflected light has been used which has killed

the shadows and destroyed the effect of relief. Careful retouching will often correct this defect.

The best prints for reproduction are made from negatives in which the illumination has been evenly distributed and the details are sharp. A print should always show soft tone effects and not be what is termed "too contrasty"; if it is, the printed reproduction will show exactly that effect. When a negative has been overexposed it will be dull or "flat" and generally unsatisfactory for reproduction. It may be full of detail but too thin to print well. When underexposed, it will show no details and the shadows will be too black.

While a good photograph of a specimen may be superior in accuracy compared with that possible to attain in a drawing, it is indeed a rarity to find a photograph in which every part is equally distinct. Focus is always an important factor, since small specimens are not only difficult to pose but impossible to focus so that all parts will appear equally sharp; but if the photographer knows the salient characters in a specimen, he can focus so as to show those parts more clearly.

The present excellence of skilled photography, with prints correctly developed and suitably retouched, should preclude the use of inferior illustrations derived from that source.

Micropaleontology.—This is a branch of photography in which there is still some experimenting. The result is that numerous methods covering individual technique are used, with varying degrees of success. Cushman* has described his method fully and specialists everywhere have found his methods intensely valuable as covering the subject of micropaleontology with especial reference to Foraminifera. The greatest difficulty to overcome is obtaining depth of focus with the desired magnification and with satisfactory lighting of the object.

A technique developed by Manley L. Natland, of the Shell Oil Company, through whose courtesy the writer has received a brief description of the apparatus used in photographing Foraminifera, is as follows:

* Joseph A. Cushman, *Contributions from the Cushman Laboratory of Foraminifera Research,* Vol. 2, pp. 1–3.

The apparatus used to photograph smaller Foraminifera is mounted in two adjoining rooms, one a projection room and the other a darkroom. In the projection room is mounted a compound microscope, with its tube tilted in a horizontal position. The microscope is equipped with low-power objectives (32.–72. mm.). The ocular is removed. The foraminifer is mounted on a rotating stage and is illuminated by two lights diametrically arranged. These lights are set so that they illuminate the specimen from a low angle of incidence, approximately 10°, and can be rotated around the specimen. The brilliance of each light is controlled by a rheostat, by means of which shadow effects can be created. The reflected image of the specimen is projected horizontally through a hole in the wall and upon a ground glass in the adjoining darkroom. The ground glass is mounted on a carriage, which is movable along a track. In this manner the distance of projection can be varied from three to sixteen feet. Therefore, by this method, the magnification is obtained not by a powerful lens system with insufficient depth of focus but rather by projecting the image several feet with low-power objectives having sufficient depth of focus to show clearly all parts of the specimen.

The remote control system, too intricate to describe here, is attached to the ground-glass carriage and enables the operator while studying the image on the ground glass to orient and regulate the lights with respect to the specimen so as to show clearly its contour and details and to bring the image into sharp focus.

Having secured a clear image on the ground glass, the remaining task is not difficult. It consists only of the selection of the proper film and the proper length of exposure. The film which I use in photographing is Eastman's Panchromatic Super-sensitive, 1⅝″ × 2½″ packs. With this film the average exposure time is approximately two seconds. The time varies with almost every object photographed; but the operator soon becomes trained so that he can determine the proper exposure time by judging the intensity of the image on the ground glass. The image photographed is usually about one inch in diameter. Since Panchromatic film is fine-grained, this image may be enlarged ten times without much loss of detail.

The enlargement mentioned is generally too great unless exceedingly minute and complex details are shown that need retouching. In all photomicroscopic work the best methods of retouching the prints and making up plate groups are practically the same as those used in larger forms and described under the headings "Retouching Photographs of Specimens" and "Making Up Plates and Grouping Figures" (see §§20, 26).

Solid black versus white backgrounds.—One mooted question in microphotography applied to all biological subjects concerns the backgrounds. In this there can be no unyielding rule

since some kinds of specimens, particularly the smaller foraminifers and other minute forms showing complex and indefinite margins, require either natural or black backgrounds for the best results.

Affirmative opinions are doubtless based upon the law of contrasts rather than the fact that every object, regardless of color or strength of color, owes its apparent shape and detail to the simple elements of light and shade. *When an object does not require enlargement,* it will show its form and detail better on a white than on a black background, as demonstrated in Plate II, which shows the comparative effects of ground tone on nearly white specimens that *do not* require the black background. These specimens were photographed each with the same focus and illumination.

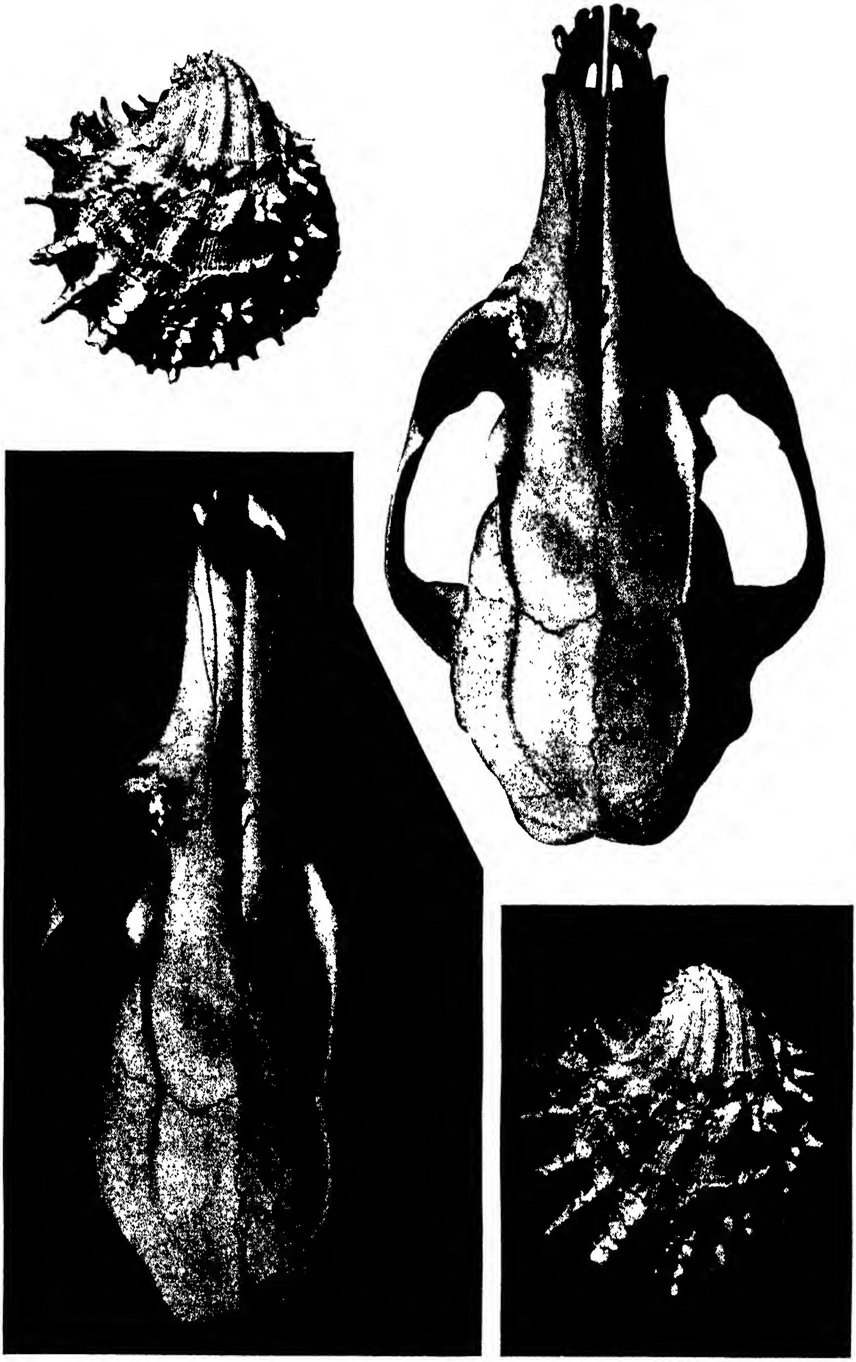
In the small, microscopic forms included in Foraminifera and other orders, however, micropaleontologists prefer the black background. These marine microorganisms, mounted on black slides, are first seen and studied as white objects on a black background, and micropaleontologists everywhere prefer to carry that impression to the finished illustration.*

Direction of light.—Since the relief or third dimension in an object is produced by light and shade, two or more photographs or photomicrographs of specimens, placed side by side on a plate, in which the illumination on each comes from a different direction, may completely change the effect of relief in one or the other, as in Plate III, which shows opposite lighting. Such a difference will be particularly noticeable in plates when made up of a number of figures that have not been consistently lighted.

In photographing scientific specimens the use of a consistent left-hand lighting has become almost universal and should be followed, since most writers, and in fact most persons using a

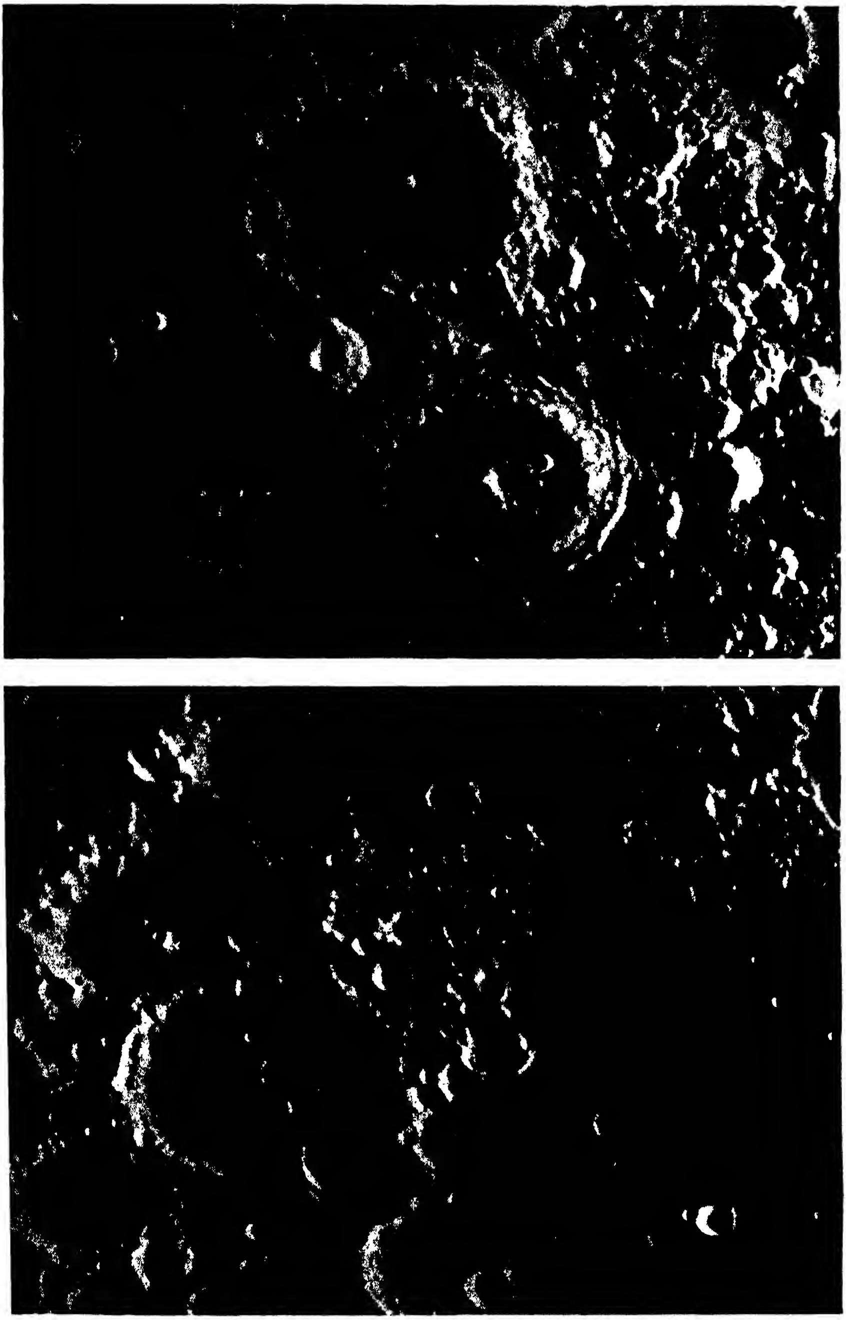
* Examples of such plates will be found in numerous reports, among which may be mentioned *Foraminifera, Their Classification and Economic Use* by Joseph A. Cushman; *Recent Littoral Foraminifera from Texas and Louisiana* by M. M. Kornfeld, published by the Stanford University Press; and *The Life History of Patellina corrugata Williamson, a Foraminifera* by Earl H. Myers. For the Cushman and Kornfeld papers, the black backgrounds were added after the drawings were made. An excellent example of microphotographs of foraminifers on a black background and reproduced by the collotype process is shown in *Contributions from the Cushman Laboratory,* Vol. 12, Part 1 (March 1936).

PLATE II



Comparative effects of white and solid black backgrounds

PLATE III



Single photograph of moon craters, cut into two parts and the lower part reversed to show complete reversal of the effect of relief in the two parts. Photograph from Mount Wilson Observatory. Page 14.

desk or table have it so placed that the light comes over their left shoulder. It is in such a light that specimens are usually examined and compared with the drawings or with other illustrations already published.

Prints made on Velox, Azo, or other unglazed, mat-surfaced paper may be retouched with pencils as described in §20, placing the prints conveniently for retouching, while viewing the specimen through the microscope, in the same position as would be required in making a camera lucida drawing directly from the microscope. The retouching would be very similar to making a drawing and not unlike the methods prescribed for other, larger subjects for which the prevailing light should come from the upper left side. The same rules covering reflected light or "counterlight" also would apply—the reflection softening the shadows and imparting to rounded or angular surfaces the effect of recession.

As Dr. Hubert G. Schenck of Stanford University states:

> The use of stereograms is of untold aid in illustrating the morphology of the larger Foraminifera. Numerous examples of these will be found in the writings of several authors, notably W. B. Carpenter, *An Introduction to the Study of the Foraminifera* (1862), and papers by I. M. van der Vlerk, Dunbar and Condra, Schenck and Aguerrevere, and many others.
>
> Illustrations of the larger Foraminifera are almost always from microphotographs. A satisfactory example is Plate 24, *Journal of Paleontology,* vol. 10 (April 1936), illustrating *fusulinids.* Orbitoidal and other larger Tertiary foraminifers, as well as the *fusulinids,* are studied from thin sections, which are photographed. The detail that may be obtained is brought out by Fig. 4*a*, Plate 36, *Proceedings of the U.S. National Museum,* vol. 83, no. 2996 (1936).

§7. Use of Textbooks on Drawing

It has been said that no book on drawing can impart an ability to draw. That is true only in part, for such books are needed and have among their uses the systematic training of persons who do not show a marked ability to draw or who lack the strong impulse and enthusiasm of the apt student. Throughout the great bulk of scientific literature it is not hard, however, to discriminate between the pictorial results of these two kinds of students. While the illustrative values of their drawings may

sometimes be equal, their value as desirable book illustrations will always be measured by their artistic effect. Whether the craftsmanship shall be deemed unimportant or each illustration shall be given proper artistic treatment is a question for each author to decide for himself; the latter is surely the most desirable.

In most textbooks on drawing the underlying principles of drawing and basic methods of procedure are fully explained. By that kind of instruction anyone with ordinary intelligence can be taught to draw in a manner, and by continued practice he will acquire a tendency toward close observation.

Close mental observation is a faculty of mind uncultivated in many persons. What they see is like a statement that does not impress the listener—it goes in one ear and out the other. It leaves no impression because no mental reaction follows the seeing. A tree, for instance, will be drawn with a continuous curved outline, regardless of the fact, and their own knowledge, that trees do not grow like that. Two objects of equal size and the same distance apart will be drawn with the three dimensions grossly unequal—all chargeable to this one failure—lack of close mental observation.

A complete treatise on drawing would require many pages of text and many illustrations; such books are available and it has been deemed unnecessary to include elementary matter of this kind in the present work. Many of these books on drawing contain comprehensive and systematic instruction of value to students of every class. One recently published, *A Manual of Drawing for Science Students,* by Justus F. Mueller,* will be found useful to those who wish to take up the study of drawing, and there are many others on the shelves of libraries and in bookstores.

§8. Essential Requirements in Drawing

It is generally believed by those who have not given much thought to the matter of drawing that in order to become proficient in such work one must engage in long and tedious

* Farrer and Rinehart, New York, 1935.

practice—as in the study of music, in which the hands are trained in the development of an exceptional technique. The fact is that dexterity has comparatively little to do with drawing. Its successful achievement is largely analytical, since what is seen must be studied, interpreted, and transferred by the artist to his paper or canvas in his own way. It was Joseph Wolf, the greatest of all animal painters, who said, "We see distinctly only what we know thoroughly." The artist may not know the classification of an object, but he must be able to understand the reason for every effect exhibited by his subject before he can draw it successfully. Skill, or the mechanical part of drawing, is of little moment, but understanding what one sees and carrying that impression to paper is quite another matter. It should be remembered that every object has three dimensions: length, breadth, and depth or thickness. A drawing therefore must first of all show a general layout or outline of the various parts and details of a subject in their correct relative positions, then their shading, and, finally, their texture and character. The casual observer views each subject as a mass without studying its various effects; the science artist looks for details and the effects of lights and shadows that bring them out. Every part is studied.

In general picture-making a broader rendering is permitted and the artist omits many details. Especially is this true in outdoor sketching or painting, yet at the same time specific differences can be shown even while rendering the broader effects of the masses (see §24).

Hence breadth and simplicity of treatment come only by experience, and that must begin in landscape drawing with a mastery of the simpler rules of linear and aerial perspective. The diminution of detail according to distance must be understood, as well as the atmospheric or tone-effect on distant objects compared with those in the foreground and middle distance. Foliage and ground character, with their unending forms and effects—all must be not merely visualized but well understood. That is, the student should know the causes by which the varying effects in nature are produced. Lights and shadows, and the scintillating effects of sunlight on foliage, with the proper shap-

ing or blocking out of its masses are points of artistic achievement which the artist has learned to appreciate by close observation, study, and experience.

One of the essential requirements in all kinds of finished drawing is that conspicuous outlines be omitted. There are no real outlines in nature. Two objects coming together do not produce a line; yet in outdoor sketching it is necessary first to outline the various parts in their proper spatial relations. These outlines should be regarded merely as guide lines; they may be erased, or may be left standing if not too conspicuous.

§9. Preparation of Illustrations by Draftsmen

The descriptive matter and references to methods of preparing scientific illustrations in this book refer not only to the subjects directly mentioned but to all the sciences. For example, in retouching photographs of fossils or landscapes (see Plates IX and X, facing pp. 58, 59), the same principles and methods would apply as to photographs to be used in botany, ornithology, mammalogy, herpetology, ichthyology, entomology, and other sciences. The same rules and kind of technique—line work, brush work, shading, proportion, etc.—apply to each.

Observation and experience in examining the work of others shows that if one can draw successfully a bird or a mammal he can draw equally well an insect, a reptile, or any other biological subject; and if he can draw successfully a fossil, he can also draw an artifact, thus covering a similar field in archaeology. The rules and elements of interpretation and sketching, light and shade, composition, and all other technical requirements needed to produce artistic and truthful results are much the same for each class of subject.

General requirements.—In freehand drawing the aim is to record what one sees and the way it looks; and science requires that this general principle be observed in preparing illustrations. But not all scientific illustrations are made freehand. Some are wholly mechanical, that is, made with instruments. They represent only a methodical arrangement of details or of something that may or may not exist. Comparison

of the two kinds of drawing will show, however, that long experience in mechanical drawing alone does not fit one for scientific work except in outline drawing and lettering, since many elements needed in freehand drawing are entirely absent in purely mechanical work.

In preparing scientific illustrations it is required that a full measure of values, including exact form and detail, be given—generally without the use of ruling pen, T-square, and triangle. It should be known, first of all, how to plan each drawing step by step for an engraved cut, a lithograph, a text figure, or a plate, always with a definite result in view. To do this successfully, a knowledge of the processes of engraving most used and the kind of copy each process demands is essential, so that the drawing will fit the requirements of a certain process and represent a fixed scale.

One of the best schools for scientific illustrating is the natural history museum. Here the various heads of departments are always willing, even anxious, to aid in the development of any latent talent the student may possess; in whatever line his interest lies, the museum generally has the material.*

§10. Materials Used in Preparing Drawings

Paper for large and important maps.—Especially for maps that may at some future time be extended to cover a greater area or that may be made to fit maps already prepared or published, the paper used should be mounted on muslin in order to reduce to a minimum the shrinking or stretching caused by changing atmospheric conditions. Pure white paper produces a better negative than a cream or yellowish paper, and since all papers become increasingly yellowish with age and exposure to light, a pure white paper is always preferred.

* In the Los Angeles Museum, under the directorship of Dr. William Alanson Bryan, there has been developed a collection of old and modern prints, in color and in monochrome, covering almost every subject under the sun from the far reaches of history to this present day. This great collection is catalogued and jacketed so that easy reference can be made to any specific subject. The present writer has had occasion to consult this collection and can highly recommend its usefulness, not only to the general public, but also to artists and to specialists in almost every branch of research.

The following brands of paper are recommended for use in preparing maps and other drawings.

Normal K. & E. Has an excellent surface and comes in flat sheets, 19 × 24, 22 × 30, and 27 × 40 inches.

Paragon K. & E., mounted on muslin. In 10-yard rolls 72 inches wide. Used for large office drawings and maps of large scale.

Anvil K. & E., mounted on muslin. In 10-yard rolls 42, 62, and 72 inches wide. Used for large drawings.

Whatman's Hot-Pressed. An excellent paper for maps. Obtainable either mounted on muslin or unmounted, comes in sheets ranging in size from 13 × 17 to 31 × 53 inches. The muslin-backed paper is recommended for use in preparing large base maps, since it is both durable and flexible and permits the map to be rolled. This makes it particularly serviceable when subjected to considerable revision, with the addition of a title, explanation, and other marginal matter. It is also useful in making drawings in washes.

Illustration board.—Used by many commercial artists, and has proved to be a satisfactory board upon which to make drawings of large specimens in washes or in color.

Ross's relief hand-stipple drawing board.—By using this board or paper, much time can be saved in producing stipple effects. It is a stiff enameled or chalk-coated paper whose surface has been compressed into minute points or other patterns that stand in slight relief so that by rubbing a pencil or crayon over it the shade is broken up into dots or lines which will reproduce. It is much used in making drawings to show relief by gradation of light and shade (see Fig. 13, *c*). It comes in sheets ranging in size from 11 × 14 to 22 × 28 inches.

Scratch board.—Also chalk-coated, and a time-saver in many kinds of drawing. Its various pattern effects are sometimes printed in black. High lights are made by scraping.

Profile and cross-section paper.—In sheets of convenient size or in rolls. Bears lines printed in blue, green, red, and orange, in many kinds of rulings, which may be selected by

reference to catalogues. That printed in orange is recommended for preliminary drawings; blue is recommended for drawings that are made in pencil by authors and submitted for inking in. The choice of color for final drawings is often controlled by whether or not the cross-section ruling is to appear in the finished print. It is advisable to consult the engraver or printer on this point.

Bristol board.—For detailed drawings made with pen especially, or with washes, and for key maps and diagrams less than 18 × 24 inches. Reynolds' Bristol board is recommended on account of its pure white color and its hardness, which permits erasures to be made without affecting redrawing over the corrected area. It is obtained in 2-ply, 3-ply, and 4-ply sheets. The 2-ply and 3-ply are especially useful in making delicate brush and pencil drawings and pen-and-ink drawings. It is obtained in sheets 16½ × 20¾, 18½ × 22⅜, and 21½ × 28¾ inches. Bristol board is made up of a number of sheets compressed together. To find the number of "ply" comprising a sheet, cut off a thin wedge-shaped piece and apply a lighted match to the thin end; the sheets quickly separate.

Cardboard or mat board for mounting.—Cardboard should be used only for mounting drawings and for making up plates and grouping figures. The face or coating of the cardboard should preferably be pure white, and it should not be so tough as to make it impossible to remove delicate drawings and photographs, as sometimes becomes necessary after they have been pasted on. When drawings or photographs have to be removed, and there is difficulty in avoiding injury to them, cut around the edges of the picture with a very sharp penknife and lift up the cardboard surface along with the illustration. The special brand of mat board recommended is made in sheets 30 × 40 inches.

Tracing cloth or linen.—Especially useful for large work that will require considerable reduction. One of its advantages is that a tracing made on it with pen and black ink can be used for direct reproduction by photoengraving, and it can also be used for making a paper negative for contact printing or blue-

printing. On the other hand, it is susceptible to atmospheric changes that affect scale, and the lines traced on it are not always reproduced as sharply as those made on paper. It can be obtained in rolls from 30 to 54 inches wide. Erasures should be made with a hard rubber eraser, not with a sand rubber or a steel eraser.

Tracing paper (onion-skin paper).—An indispensable adjunct in drawing or in preparing illustrations. While tracing linen is used for making permanent drawings, the principal use of tracing paper is to trace and transfer. Its general use is, of course, well known. It is found useful also in recording parts to be eliminated when corrections are made and for the purpose of comparing and adjusting outlines. There are several qualities on the market, some of which lack the transparency often needed.

Inks.—Drawing inks in liquid form should be waterproof and equal to the grade known as Higgins' Waterproof Ink. When a suitable waterproof blue ink cannot be obtained, a good blue for features of drainage can be made by dissolving a half pan of Winsor & Newton's Prussian blue in water. No good waterproof burnt sienna ink seems to be obtainable, but a good substitute can be made by dissolving Winsor & Newton's water color of that name. Neither of these, however, is waterproof.

All ink lines should be drawn in full strength of color, and pens should be kept clean. The same pen should not be used for applying two inks, as the mixture thus produced is likely to thicken or coagulate on the pen. A little black should be added to colored inks when the drawings are to be photographed or reproduced in colors, in order to strengthen their actinic value.

Drawing pens.—Those made by Keuffel & Esser, especially their No. 3202, and Gillott's Nos. 291, 290, 170, and 303 give complete satisfaction. The Gillott numbers are given in their order of fineness of points, No. 291 being the finest. The best cleaner for a drawing pen is a piece of chamois skin. Pencil guide lines should be very carefully removed with a soft rubber.

Pencils.—Drawing pencils should have leads of a smoothness and quality equal to those of the Koh-i-noor brand, in which the grades of hardness are indicated by 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, 8H, 9H; the softest grade in the list is 3B and the hardest is 9H. The grades most generally used are BB, B, HB, F, 6H, and 9H. There are other brands of pencils that are entirely satisfactory, including Dixon's, VanDyk, and others.

Rubber erasers and cleaners.—There are two kinds of rubber erasers usually employed in making erasures on drawings—a hard, dense rubber like the "Ruby," "Venus," or "H" (Hardtmuth), and a soft, pliable rubber like "Artex 400." The soft rubber is also useful for cleaning large surfaces. Art gum, also recommended for this purpose, has the advantage of not disturbing the surface of the paper.

Modeler's clay (Plasteline).—Indispensable for posing specimens in positions required for drawing. It comes in small paper cartons and can be purchased in art stores.

Water colors.—Those made by Winsor & Newton, Devoe, Keuffel & Esser, and others are standard brands and are good in every way; they come in full and half pans. There are other and cheaper brands of colors to be found in art stores, some of which have proved to answer every purpose of the colorist.

Colored pencils and crayons.—No special make is recommended. There are many varieties on the market to select from, including Mongol indelible pencils in boxes of twelve and twenty-four, each in a separate color with wax base; also Castel colored pencils. These are softer and not indelible. They can be obtained separately in any color.

Japanese transparent water colors.—These colors come in book form, which makes them especially useful and convenient for field use. They are recommended only for coloring maps or other subjects in which it is important to discriminate parts or areas.

Photo-paste, library paste, ordinary mucilage.—These are recommended for pasting on reference letters and numbers. Carter's "Cico" liquid paste will be found to be satisfactory,

especially for small work. Suggestions for applying these adhesives will be found in §38.

Liquid rubber and white rubber cement.—Recommended for use for temporary mounts. It avoids buckling or warping of the paper and is often serviceable in mounting full-size photographs on cards or in albums. (See also §26.)

Oxgall.—Sometimes used in connection with water colors. Especially useful on smooth or glossy surfaces to which the pigment adheres more readily.

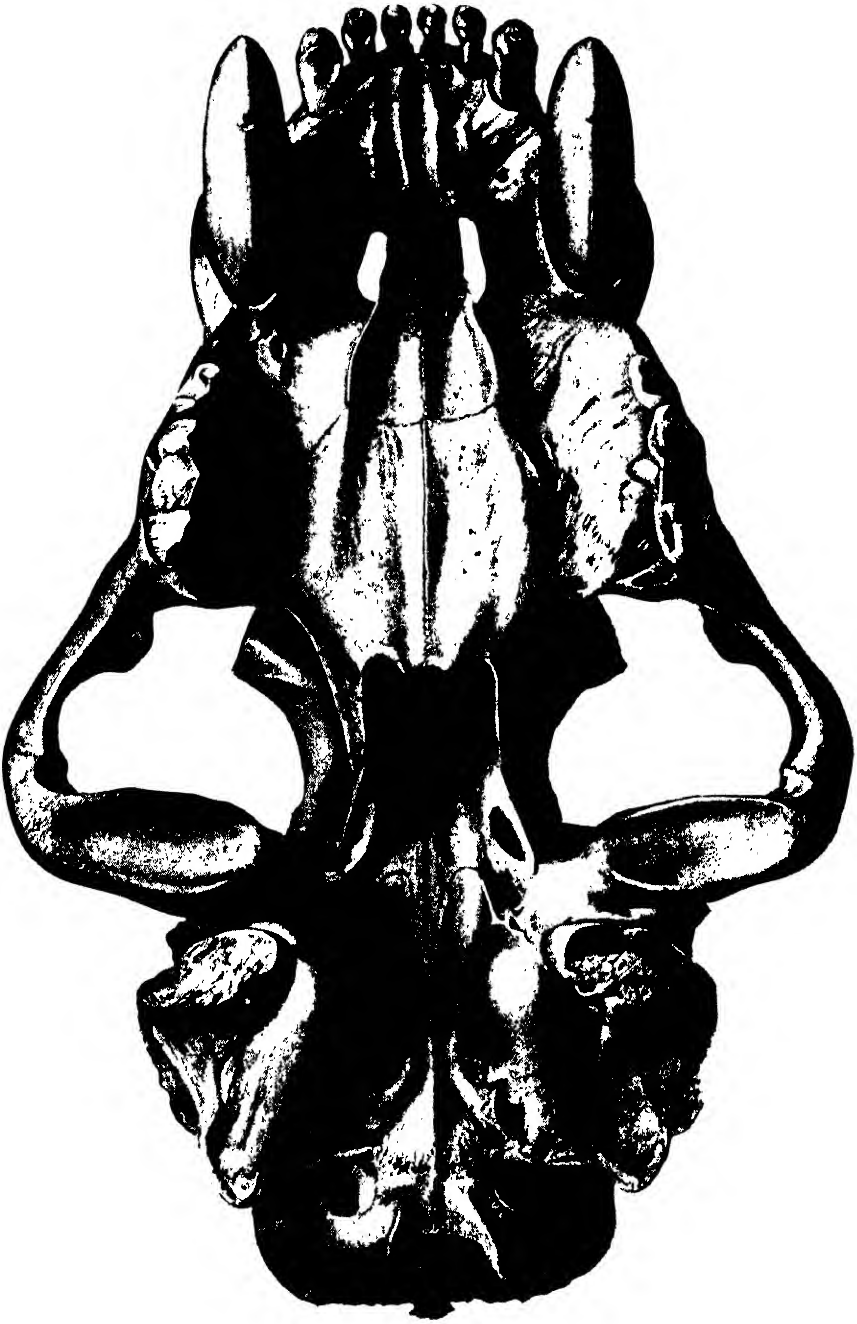
Scotch Holdfast Drafting Tape.—Very useful in holding drawing paper on a board, and in temporarily fastening tracing paper and other oversheets for copying. It is put up in cartons of 10- and 72-yard rolls.

§11. Instruments Needed

The following list of draftsmen's instruments includes those which are considered indispensable for general work, and are marked by asterisks; the others may be used according to individual preference. The same kind of instrument may be duplicated in different sizes according to the varying demands of work.

Air brush and connections
*Beam compass
Bow pen, drop spring
*Bow pen, steel spring
Bow pencil, steel spring
*Brushes, red sable, No. 2 to No. 8
Camera lucida
*China saucers
*Color box and W. & N. colors
*Compass, pen and pencil points
Crayons, assorted colors
Curve rule, adjustable
*Dividers, proportional
*Dividers, plain
Dividers, steel spring
Drawing boards, several sizes
Eraser, glass
*Eraser, steel
Erasing shield
*French curves, xylonite
Hand lens—2-inch focal distance
*Hand mirror, small
Microscope, and lenses
Palette knife
Pantograph
Pens, double-pointed
*Pens, Gillott's, Nos. 170, 291, 290
Pens, drawing, K. & E., No. 3202
Pens, Payzant's, 1 set
*Pencils, best quality, graded leads
*Protractor
Railroad curves, pearwood, 1 set
Railroad pen
*Railroad pencil
*Reading glass
*Reducing glass
*Ruling pen
*Sand block

PLATE IV



Brush drawing of ventral view of skull of saber-toothed tiger. Drawn in full light and shade, and reduced approximately one-third. Los Angeles Museum Collection.

*Scale, boxwood, 12 inches long, with divisions of millimeters and inches. Scales, boxwood, triangular
Section liner (parallel ruling device)
Straightedge, steel, 24 inches
*Straightedge, wood, 24 inches
Swivel or contour pen
Stub, for blending
*Thumbtacks
Tracing point, steel
*Triangle, 45°
*Triangle, 60°
*T square, pearwood, xylonite or celluloid edge
*Tweezers, dentist's, with curved points
*Straightedge, steel, 36 inches, with divisions for hundredths of an inch and millimeters

§12. Posing Specimens (Orientation)

In most natural sciences there are certain definite rules that should govern the pose or attitude of specimens when they are figured. Pose has an important bearing on the making of illustrations, particularly for the reason that it is often necessary to compare published figures with others when a variation in attitude or orientation would make close comparison difficult. The lighting should come from the upper left.

In *archaeology,* all artifacts are figured in positions suggested by their use as far as that can be determined by examining prehistoric and aboriginal specimens. It sometimes happens, however, that a certain feature or character can be shown only by a change in position from normal, and a pose best suited to display that character is always selected (see Fig. 1).

In *vertebrate paleontology,* limb bones are figured squarely from the front, with the proximal end above and the distal end below. Large skulls are generally figured with the dorsal and ventral views in a vertical position with the anterior end above, while the lateral view of the same skull is shown in a horizontal position. Other skeletal elements are figured in positions which conform in a general way to their positions in the skeleton, which will also show their proximal and distal ends; but when figured separately the long axis of each element is always given either a vertical or a horizontal position and figured squarely from its anterior or front side. If additional views of a single element are needed, the lateral view is shown squarely at right angles to the first view and the ventral view is shown directly opposite the first or front view.

FIG. 1.—Pen-and-ink drawings of artifacts, reduced one-third linear

In *invertebrate paleontology,* all mollusks are shown with the apex and the umbo at the top. The gastropods should be posed so that all division lines between the whorls are straight, turning just slightly at the ends. When these division lines are curved the specimen has not been properly posed. The surface plane of the aperture should be square with the eye, and all reverse views of a specimen should be exactly opposite. (See Fig. 2.)

In *paleobotany* (see §21) the long axis or midrib of a leaf should be vertical, with the tip above and the stem below. In

the portrayal of living forms, nature should be followed in general.

In *micropaleontology,* certain definite rules for posing specimens, which are largely traditional, should persist. They cannot be satisfactorily described on account of the almost infinite number of forms in each group, but specialists will do well to adopt the prevailing customs used by other investigators in each group. This will facilitate closer comparison with published figures. The use of black or white backgrounds for such subjects is discussed above in §6.

In *ornithology,* the heads, bills, feet, and wings of birds are usually shown in approximately their natural positions, while eggs are best shown with their points down. (See plates in Bendire's

Fig. 2.—Pen-and-ink drawings of invertebrate fossils, reduced one-third linear.

Life Histories of North American Birds, Volumes I and II, prepared by this author.)

In *entomology,* natural positions are sought. Larvae, pupae, chrysales, etc., when not attached, may be figured either vertically or horizontally.

For *crystallography,* the general rules for drawing are given in §17.

In *mineralogy,* specimens are figured in positions which display the essential features to best advantage. When such a feature is in shadow, some reflected light will aid in its development.

Before making drawings or having drawings made for the purpose of illustration, the matter of correct posing of each kind of specimen should be given careful consideration in order to make the figure agree with standard usage. (See §18 for characteristic attitudes of living forms.)

§13. The Drawing of Specimens

Specimen drawing naturally covers a very large and diversified field. In work of this kind the first requisite is posing the specimen as referred to under the preceding heading. Hard, compact specimens, such as megafossils, minerals, artifacts, and many others, are easily placed in position by pressing them or propping them in Plasteline or modeler's clay. But many kinds of specimens composed of soft, pliant, and fragile material require more delicate posing. Sometimes considerable ingenuity is needed to hold such specimens in position while being drawn. For very delicate specimens, absorbent cotton can be used as a bed upon which a specimen may be posed in its required position. In microscopic work minute specimens are usually mounted on cards upon which they are, or should be, properly oriented before being drawn. After posing the specimen which, as one simple example, may be a small fossil bone of an extinct mammal, the scale of the drawing and the space it will occupy on the paper must be determined first. To do this it will be assumed that the artist's equipment will include good proportional dividers.

The next consideration would be the process by which the drawing will be reproduced. This will decide what medium shall be used in making the drawing. If it is to be a text figure, a pen drawing would be made for a line cut, and the drawing should be twice the size of the printed illustration. If it is to be full scale, i.e., the size of the specimen, it will probably be made for reduction to one-half natural size. All drawings should be made not only for a particular process of engraving, but to a scale which, when engraved, can be referred to by a simple fraction or multiple as ½, ¼, or 1½ times natural size, etc.* Drawing to definite scale entails no difficulties, but in a pen drawing the spacing of shade lines often becomes a problem. In lettering, the unit of measure is one millimeter for the smallest letter; but this cannot be applied to shade lines. Personal judgment, therefore, is needed, and this is generally founded on experience. The scale having been decided, the specimen which has been firmly anchored in modeler's clay is placed at a distance from the eye that will afford a plain vision of every detail—15 inches being generally the proper distance.

The light should come from the upper left and there should be a sufficient reflection of light to subdue the shadows slightly and at the same time produce the effect of recession in the shaded parts.

Unless a camera lucida is preferred, after the specimen has been posed the cardboard square described in §14 should be set up in contact with the specimen and all measurements taken from the inner edge of this square to the various points on the specimen, as shown in Figure 3. It is also necessary that the specimen and the inclination of the square be exactly at right angles to the line of sight; and all measurements should be taken under these conditions. It should then be decided whether the drawing will be a text figure or will be assembled with others on a plate. If for a plate, the drawing would probably be made in washes for half-tone reproduction; but, as already stated, there is no rule limiting the processes of engraving illustrations

* The indication of "size" by the statements $\times$ 1 and $\times$ ½, used by some authors to mean natural size and one-half natural size, is somewhat ambiguous; to the uninitiated they might mean 2 times and one and one-half times natural size, respectively.

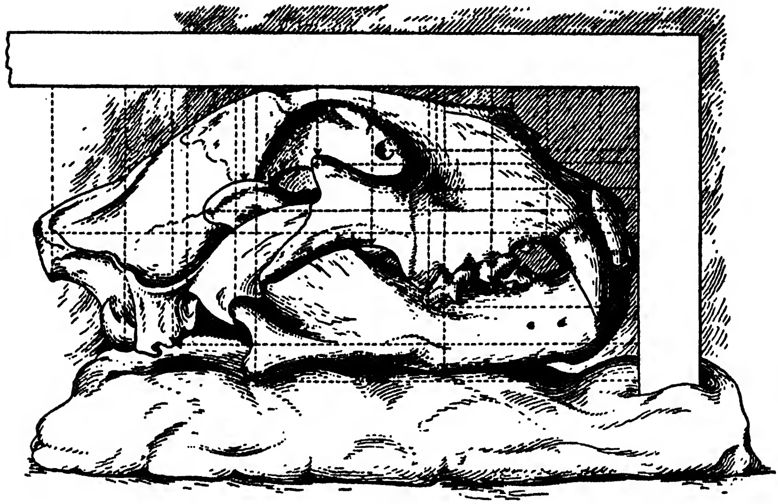


FIG. 3.—Sketch showing method of taking measurements by use of cardboard square

for so-called plates, as any of the processes of reproduction are appropriate.

In preparing such a drawing the first important step would be a preliminary, carefully prepared pencil sketch, on the scale decided upon, and on a good quality of Bristol board, or, as preferred by some artists, Whatman's Hot-Pressed or other smooth-surfaced paper. The sketch should include the location of every essential detail and faint outlines of all shadows, so that while using the medium to complete the drawing not many additional measurements will be necessary. It is sometimes helpful in making drawings of fossils to represent some of the major cracks or breaks. These aid not only in preserving surface character but also in accentuating or bringing out form. When the carefully prepared sketch has been approved, the shading and development of the drawing is next in order. If the drawing is to be made with pen, it has been found that pens equal to Gillott's 291 and Higgins' black waterproof ink are well suited to the purpose. Sometimes for work that is to be greatly reduced a coarser pen, equal to Gillott's 170, will be preferable. In all pen drawing every line and every dot should be sufficiently strong to reproduce well, whether greatly reduced or not. Scratchy lines are taboo.

If the drawing is to be made in washes, red-sable brushes (sizes ranging from No. 2 to No. 4) and lampblack, India ink, or sepia, would be appropriate. Soft effects can easily be produced by each of these pigments, but lampblack is the one generally used. The successful accomplishment of the drawing will also depend largely upon the angle and strength of the normal light rays, with sufficient reflected light from within the room to illuminate the specimen slightly on the shaded side.

Brush and pencil drawings of specimens.—The preliminary pencil sketch needed for a shaded brush or pencil drawing (as in all specimen work) is made as just described, using the cardboard square for taking measurements. Or, if preferred, a camera lucida may be used. In all such drawings (as well as photographs of specimens) a disregard of the well-established rule already referred to, and exemplified in Plates III and V,* that the direction of illumination should be uniformly from the left, would cause confusion or uncertainty in the interpretation of relief when the drawings are assembled in combination.

In making colored drawings from specimens, transparent water colors should be used, and for black-and-white drawings either lampblack or stick India ink is recommended. With either of these pigments the soft, delicate shading generally needed in such work can be produced as shown in Plates III and V, which were drawn on Reynolds' Bristol board with lampblack as the color pigment. The use of much penciling in connection with brush work in drawing specimens is not desirable, except in making the preliminary outline sketch and in slightly sharpening edges or indicating very minute details. Care should be taken that the pressure of the point is not too strong. An F and B pencil will be found most suitable for this purpose.

Body color, an opaque mixture of Chinese white with lampblack or other pigments (sometimes known as "gouache"), may also be used but it is not as satisfactory for the drawing of specimens as transparent washes. Its use is directed more to larger and more pictorial work, including outdoor scenes and figure drawing, and is much used by commercial artists.

* See pp. 14 and 39.

In making corrections on brush drawings that have been made on Bristol board, one should carefully wash out with a small short-cropped brush and clear water any parts that may need correcting and, when perfectly dry, clean still further by using an ordinary rubber eraser over an erasing shield or an opening cut in a piece of paper or thin celluloid. Erasures should not be made on small or delicate drawings with a knife or a sand rubber, as these would tend to injure the surface and possibly affect the reproduction. In measuring with dividers one must take care not to injure the specimen or to puncture the paper on which the drawing is being made.

Very satisfactory and delicate drawings of specimens can be made also entirely with pencils. The reproduction of such drawings is not as strong as that made from wash drawings, and they are easily smeared if not carefully protected. Three-ply and four-ply Bristol board and pencils of the grades of B, F, 4H, and 6H are recommended for this purpose.

Pen drawings of specimens.—The preliminary pencil sketch for a pen drawing should be prepared in much the same manner as in other kinds of drawing (see §13) but be more complete in detail, even though it will be used only as a guide. The pen work should begin with the outlines and proceed to details and shading, whether in lines or in stipple. The texture of a specimen is the best key to the proper shading. If the specimen is decidedly granular, stippling is sometimes (but not always) appropriate; if it is smooth and shows no detail, fine parallel lines drawn in the general direction of curvature and varied in spacing and character according to shade and texture are generally indicated. Erasures can be made with a hard rubber eraser (other parts being protected by a shield) or with a very sharp knife. The parts erased can be resurfaced with a burnisher. Gillott's pens Nos. 291 and 170, and Higgins' black waterproof ink are recommended. Reynolds' Bristol board should generally be used because of the perfection with which erasures can be made on it when they are needed.

The technique of completely shaded pen drawing is more difficult than that of brush work. It is a kind of drawing in

which both characteristic detail and shading can be shown only in lines and dots and white and black areas. This offers the greatest difficulty, because the shading is liable to confuse and destroy both. Especially is this true in the drawing of invertebrate shells in which the surface structure usually consists of lines of growth and details of sculpture. In a pen drawing of such a subject advantage should be taken of these surface lines by filling in and thickening the lines in order to produce the necessary shading. No cross-hatching should be attempted. The direction of the lines of growth should be followed very carefully, but faded off in the lighter areas. When a surface is smooth and shows no special character, the shade lines should follow the direction of slope; that is, if a surface is round, the lines should be turned in the direction of curvature; if it is flat, the lines should be straight and more regular. By following this system the form or shape of an object becomes more apparent.

In most invertebrate shell work the ventral surface or aperture is stippled in order to show contrast with the outer shell. Sometimes it is first drawn in lines following its general curvature and then stippled to an even gradation over the lines. (This method saves considerable time, but was not used in drawing Figure 2.) For many good examples of this class of work the reader is referred to the Miocene plates in the report of the Maryland Geological Survey for 1904. The drawings in that report were made by the late Dr. J. C. McConnell, who excelled in this class of invertebrate drawing.

A science artist's kit.—The special equipment found to be most useful in drawing specimens and other subjects of scientific interest consists of the following items:

Color box and water colors
Porcelain saucer
Lampblack and India ink, in cake form
Red-sable brushes Nos. 3, 4, and 7
Glass or cup for water
Hard-rubber eraser
Soft rubber or cleaner
Penknife, very sharp
Sand block for pointing pencils
Pencils of the grades of B, F, 4H, and 6H
Quantity of Plasteline or modeler's clay for posing specimens
Higgins' waterproof India ink
Gillott's pens Nos. 290, 291, and 170, or their equivalent
Chinese white, bottle or pan
"Stub" made of cork for blending
Shield to protect parts during erasures

The special instruments needed are:

- Plain dividers
- Proportional dividers
- Reading glass, 3-inch lens
- Pocket magnifier, 2-inch focal distance
- Small mirror for reflecting light
- Camera lucida

In microscopic work it is of course necessary to have access to a microscope.

§14. Outlining from Inanimate Specimens

Co-ordinate measurements. — After decision as to scale, which must govern the size of the drawing to be made, an outline pencil sketch in the pose required is next in order, and this must be controlled by accurate measurements. The method of measuring best suited to the drawing of hand specimens is referred to as a system of co-ordinate measurements.

In order that these measurements may be taken at given points on a specimen, a right-angled cardboard square* should be made and set up along the side of the specimen as shown in Figure 3, one arm of the square being firmly anchored in clay. As already stated, it is important that the inclination of the cardboard square be exactly at right angles to the line of sight—the same inclination being always given to the specimen. First find the position the figure will occupy on the paper, and draw faintly, from a right-angled triangle, lines representing the inside edge of the cardboard square. From these penciled lines locate conspicuous points on the specimen with dividers, with which all measurements are taken, and record these on the paper with the point of the pencil at the intersection of each two measurements taken horizontally and vertically. The number of points located will depend upon the character of the specimen, whether it is a plain and simple subject or one that consists of a labyrinth of details such as are shown in Plate IV, in which this system was used. The sketching should be made from the points indicated with a medium-grade pencil, and the sketch should show the complete outlines with all prominent details and

* A simple device, adjustable and of permanent character, to replace the cardboard square, is shown in Figure 4. It can be made at a cost of about $2.00.

some indication of shading, before brush or pen is used to complete the drawing.

The cardboard square can sometimes be replaced to advantage by a white or black thread stretched vertically or horizontally (sometimes both ways) across the specimen, the threads being anchored with clay or gum. The object of this thread or line is to give control to the drawing by measuring each point from the threads — which have been indicated by lines on the paper—thus giving a more accurate plotting of details. For example, if a specimen shows the slightest lateral curvature, by this method that curvature can be accurately plotted. In using either method (square or thread) much practice is required in drawing specimens showing considerable depth or relief to keep both points of the compass at an equal distance from the eye. This requires some experience and can be facilitated greatly by locating as many points as possible on the paper and proving them by measurements in different directions.

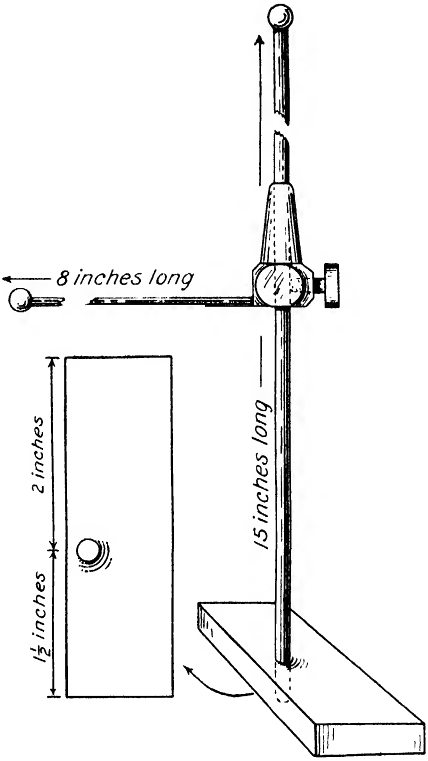


Fig. 4.—Sketch of simple device to replace cardboard square in taking measurements of specimens.

For both brush and pen drawings the pencil sketch should include faint indications of all shadows. This leaves a free hand for pen or brush and it then remains only to select the direction and character of lines to be used in the pen work or to produce the soft blending effect of light and shade and necessary detail in the brush work.

Camera lucida.—Many drawings of specimens are prepared by the use of a camera lucida, a device by which the image of the object viewed through a prism is projected on a sheet of paper so that it can be traced in outline. When drawing hand specimens, an adjustment can be made that will enlarge or reduce the scale of the image at will. It is particularly useful in drawing flimsy and fragile specimens that cannot be effectively posed in clay. In microscopic or micrographic work its use in connection with the microscope is of course of major importance.

One difficulty in using the camera lucida is the danger of foreshortening or other distortion caused by a slight tipping of the specimen or object. It should be borne in mind that the specimen must always be posed with the surface plane and vertical axis exactly at right angles to the line of sight. The instrument is a very useful device for tracing accurate outlines and details, thus eliminating the bugbear of many measurements. In hand specimens it requires much practice to overcome some of the difficulties always encountered by beginners.

Pantograph.—The principal use of the pantograph has always been in the tracing of maps and charts at either reduced or enlarged scale, for which purpose it is almost indispensable. The instrument is, however, also very useful even to experienced draftsmen in delineating specimens of large dimensions by means of which outlines and details may be traced more quickly and with a measure of accuracy not always possible by other mechanical methods. Considerable experience is required in adjusting the instrument to any desired scale, but by continued use this difficulty is easily overcome.

The writer has used the pantograph in tracing the outlines and major details of the head of a fossil cetacean, as follows:

A pantograph made by Gruner & Reinhardt, Germany, was used. It should be understood, however, that other pantographs on sale by American firms or representatives have equal efficiency. The specimen referred to was posed on a box placed immediately below the end of a large table upon which the pantograph had been adjusted to a scale of one-third natural size.

A tracing point having been provided which extended downward to the specimen (in the present instance about 12 inches), the outline and major details were thus traced and the required outline drawing recorded in the usual manner on the paper. The result of this operation was entirely successful, and it is recommended as producing a satisfactory outline drawing at a considerable saving of time over the older method of measuring with dividers.

In drawing the outlines of specimens showing considerable relief, for example, any of the larger skulls viewed from any desired aspect, the pantograph is also most useful. Especially is this true in tracing the dorsal view, which shows the greatest convexity; but it applies as well to the lateral view, in which the zygomatic arch is always difficult to locate with exactness by measurements. It should be understood, however, that the pantograph is not applicable to small specimens, for which the camera lucida would be more suitable.

§15. Specimen Drawing Compared with Restorations

While the general principles of drawing are much the same in each class of artistic work and in work approaching the artistic, there is a marked difference between specimen drawing—which is realistic still life—and the drawing of living and extinct forms of life from imperfect or fragmentary material, since the latter should show some breadth of artistic treatment.

No directions are offered here for making life studies of either living or extinct forms of life. Artists capable of doing such work exercise their own judgment and work according to their knowledge of the individual subject. For those who wish to take up this class of drawing, suggestions are offered in §18.

Whereas, in still-life subjects, an artist draws what he sees and the way it looks, a restoration is based on imperfect material and is largely imaginative; for the material only suggests a similar living creature, which becomes the basis for the reconstruction. There is some danger, however, in making a comparative study of living species with related prehistoric types. With a clear mental image of one particular living species

and a proper conception of its total organization, too much similarity is likely to show in the restoration (see §18).

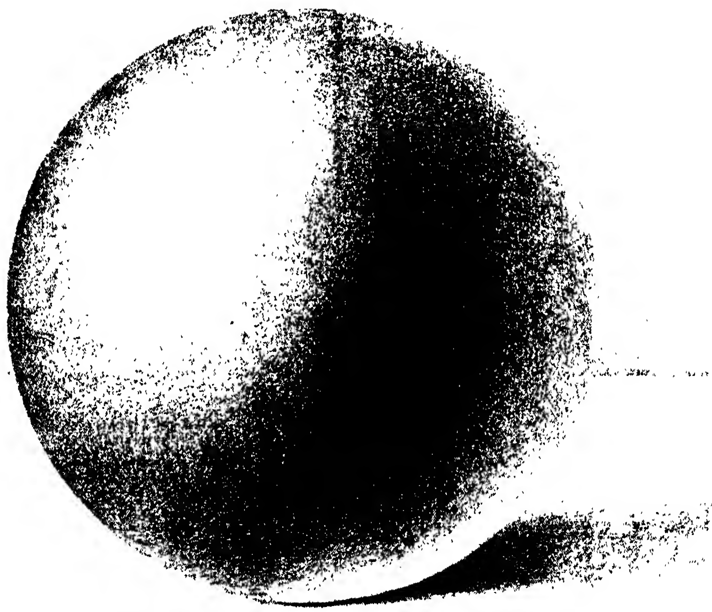
There is also a slight difference between a restoration of an extinct form of life and a drawing made from the dried skin or pelt of a living form, since more definite evidence of the outer aspect in the latter is disclosed and a greater number of related types are available for study. Imagination, therefore, plays a lesser part in the making of such a drawing, and is entirely absent in the drawing of still-life or inanimate subjects.

Restored parts.—The method of showing restored or reconstructed parts in a drawing or photograph is as follows: In line work the restored parts are shown with dotted or dashed lines. In photographs and shaded drawings the restored parts are best shown with a diagonal ruling across the restored area after the drawing has been finished.

§16. Light and Shade (Illumination)

The true form of an object (except mere outline) can be represented only by light and shade. Remove them and the object will lose its true expression of relief. Then again, direction of light rays plays an important part in showing form and bringing out detail. One part must show light and the other a shade. For example, a groove should show one side light and the other side dark, and this effect can be produced only by oblique rays—assuming that the groove runs in a direction opposed to the light rays. If the rays were vertical there would be no contrast and therefore no perceptible depth of structure. The importance of the direction of light is well shown in the effect of sunlight on foothills or mountains. At midday when the rays of light are approximately vertical there will be seen but little if any configuration, while at mid-afternoon and mid-forenoon the deeply cut ravines and canyons and the spurs and crests of ridges stand out in strong contrast and in comparative detail. It is on these simple elements of light and shade, together with other slightly more advanced principles, that the shading of drawings must depend in order to show the exact form of an object. (See Plate V, *B*.)

PLATE V



Pencil drawing of globe in full light and shade

B. Wash drawing of fossil lion skull (*Felis atrox*). Approximate scale ⅓ natural size. Los Angeles Museum Collection. See pp. 38–39.

To shade a drawing properly, a specimen should be placed in a light coming from the upper left and at an angle of about 45°. If normal daylight is used, the window should be large enough for the diffused light of the room to produce reflex illumination sufficient to soften slightly the shaded parts of the specimen; and if its surface is curved, as in Plate V, *A*, the shade will be faded off according to its distance from the eye. This effect can be given to all the shadows in both large and small areas in a drawing—even minute surfaces—when reflected light is properly manipulated. Its use within certain limits of strength is the basis for producing the most refined effects of light and shade. If, however, reflected light is too strong, the effect of relief is often ruined. The same general principles apply also to artificial light.

These principles of light and shade are applicable to every drawing in which the relief or third dimension is to be shown, and may be represented in the single example of a completely shaded drawing of a globe. An analysis of the light and shade shown on such an object (see Plate V, *A*), if properly illuminated, will be found to include every phase of light, middle tone, shadow, and reflected light. These four elements or qualities are inherent in every object and every detail, whether large or minute, simple or complex.

A globe when exposed to proper illumination offers an excellent study for the mastery of light and shade. It should be further noted, however, that if such an object has a polished or glossy surface, one more principle is involved. For example, the lighted portion of a billiard ball will show a highlight or "bead," which is the focal point of the light rays as reflected to the eye of the observer, while the point directly opposite on the shaded side will show the darkest area. This represents that part of the shadow upon which the rays of reflected light strike the object most obliquely and therefore less strongly. The polished globe will also show stronger shadows and more vivid reflections. A similar object with a dull unpolished surface will show no highlight or "bead," and reflected light upon it will be more evenly distributed.

In shading a drawing of any scientific object one should remember that the gradation of light into shadows should be as near perfection as it is humanly possible to make it. To do this, one should have always in mind the fact that a good photographic print represents this perfection of smoothness and the nearest one can approach that degree of refinement will still represent a certain crudity as compared with nature.

§17. Crystal Drawing

There are certain standard textbooks in which the several systems of projection of crystal figures are explained in great detail. The illustrator, however, does not need, nor is he supposed to know the details of all of these systems. If he did, it is not impossible that he, too, might have become interested in crystallography, for one is not apt to master the various details of crystal structure and form and the several systems of projection used in representing them unless he is greatly interested in that particular science.

The student of crystallography thus finds it necessary to prepare drawings as an aid in describing the various faces of crystals, and to do this he must understand their projection according to standard usage. Such drawings are called originals and, while correct in statement, they are not as a rule suitable for reproduction as book illustrations.

It is to this redrawing of the author's originals in proper form for publication that the following brief suggestions refer:

A crystal should generally be drawn in outline with straight lines. The invisible rear side of a crystal, if shown, should be represented by dashed lines. The outer boundary line of a crystal should be slightly heavier than the inside lines, which should all be of the same weight. Striations should be shown by straight lines; broken or uneven surfaces by irregular lines. A twinning line, if an intersection edge, should be solid; if not an intersection edge, it should be broken into dashes. Italic, Greek, German, and Old English letters are used to mark crystal faces. All faces of a given form should be marked by the same letter but may be differentiated, if necessary, by primes or numerals, thus:

m, m', m'', m''', m^iv. "Leaders" should be short, full lines, or, if these are likely to be confusing, they should be dashes. Numbers may be used in place of letters for specific purposes. Letters indicating twin faces are underscored; a second twin is doubly underscored or overscored, thus: $\underline{m}$, $\underline{\underline{m}}$, $\overline{m}$. Twin units may be differentiated by the use of roman numerals.

Drawings of crystals should be prepared twice publication size, so that when reproduced by line engraving they may be marked for "½ off" or "reduce ½." Reduction improves the effect of all drawings made with a pen. There are no exceptions to this rule.

§18. Natural History Drawing

The methods pursued in natural history drawing differ as greatly as do individual techniques. Yet it is a class of work in which certain underlying principles are common to all.

To the amateur bird artist it might be said that every part of the bird in a drawing should show character—scarcely one point is more important than another. To make a successful drawing he should know something of the anatomy and the major elements of the bird skeleton, for only upon such knowledge and its imaginary outline beneath the feathers can he intelligently fashion a bird. Only such knowledge will enable him to locate properly every part and appendage, the wings, legs, shoulder, neck, and tail. Experience in taxidermy to the extent of making bird skins will be found to be of inestimable advantage.

Next comes the exterior or superficial aspect, which will require his serious thought and artistic ability. It calls for a careful study of feather tracts, direction of shafts which control the color markings, and especially the formula, or arrangement, of wing feathers, which are usually greatly disordered in cabinet specimens and cannot be depended upon in representing a living bird. The latter is extremely important and its successful working out will be aided by examining freshly killed specimens. The position of the legs is also important, since it is necessary to give the bird correct balance and to main-

tain its specific gravity while in a standing position. Then the development of the toes, paying close attention to the joints and, in arboreal species, the characteristic "grip" upon that to which they may be attached. In short, every part of a successful bird drawing should show individual character and expression.

The first step in drawing a bird is a preliminary trial sketch of the specimen in the attitude desired, giving it position on the paper in accordance with a preconceived arrangement of the finished plate or picture. In order to do this and to show the specimen in a characteristic pose and environment, a knowledge of its habits is of course necessary. If an artist does not know his subject and is not familiar with any closely related type, it is sometimes possible to consult other illustrations of a type of subject similar to the one he is to portray; but too much reliance cannot always be placed upon such a study.

After the preliminary sketch has been made (which may be the result of numerous trials) and before beginning the final drawing, the figure to be illustrated, together with accessories, is sketched in lightly so that the completed pencil sketch will show the composition of the drawing in some detail. It may then be transferred to the drawing paper, upon which the figure of the bird is carefully checked by again measuring each feature, taking into account all necessary foreshortening according to its assumed attitude; then develop details and complete the picture.

The matter of a special "characteristic attitude," or pose of any particular species is, in the writer's opinion, often overrated, since every living thing adopts many positions which may all be assumed as characteristic and natural.

Besides characteristic attitude, "expression"* is another important phase of the work. In some mammals it is shown most strongly in the pose of the ears and the attitude of the body. Then the mouth, the eyes, and even the raising of the fur register temporary moods.

In the drawing of birds, expression is different. The turning of the head one way or another and the fluffing of its feathers

* See Darwin, "The Expression of the Emotions in Man and Animals," *Origin of Species.*

are the more conspicuous ways in which a bird can express itself except in song. But after all, its pose or attitude (which is often indicative only of what the bird will do next), the feather tracts, wing coverts, details of the eyes, bill, and feet, are each important studies that require careful attention. One who wishes to delve in bird portraiture must make a very careful study of all of these details, and their successful treatment will do much to produce a more lifelike result.

In *mammalogy,* in addition to the skeleton, the anatomy must be well understood, especially the location of the prominent muscles, which is particularly important in the drawing of short-haired species. Correct muscular development in such a drawing is absolutely essential, and no successful drawing can be made unless it covers this kind of detail. In case of a restoration of an extinct type the basis for measurement must be the skeleton, and its superficial aspect can be taken only from closely allied living types.

These generalized suggestions relate as well to other vertebrate types.

In the drawing of botanical specimens, specific character and details are generally apparent and the successful drawing therefore needs only that the touch of nature or life be added by the artist. In some kinds of specimens, the ecology can be represented in a manner similar to that used in bird, mammal, and other natural history drawings in which habitat is usually suggested in the background and accessories.

Accessories.—In the more pictorial drawings of birds, mammals, and other life studies, accessories if properly made lend an important quality of realism to the picture. The purpose of accessories is therefore twofold: first, to suggest normal environment; and, second, to present a more complete and artistic picture or plate as a whole.

One important point in adding suitable accessories is the question of relative strength of color and detail in working up that part of the picture. The effect of an illustration of this kind is sometimes enhanced by subordinating tone values in the background and accessories somewhat as shown in Plate VI,

thereby strengthening by contrast the more important and dominant figures in the picture.

It is also suggested that in drawing accessories of bird pictures especially, a scene showing the horizon should rarely if ever be added as a background. In such pictures the birds, which are almost infinitesimal compared with the landscape, are always enormously exaggerated. Simple accessories serve their purpose quite as well.

Accessories or backgrounds for natural history subjects are shown generally in two ways. In one they are vignetted—in the other, the picture is carried out to the margin. Here is matter for individual preference, but for book-plate illustrations the vignetted background can be made artistic if well balanced, and it will show "habitat" quite as well as a bit of completed scenery.

Entomology.—The various kinds of technique used in drawing do not necessarily change in their application to any particular group of subjects. If the object is to be drawn by a professional draftsman, in pen and ink, for example, the purely mechanical part of his work will require no alteration to make it applicable to the subject in hand; but the draftsman will need to know what to draw, how much to include, and how it shall be represented. Hence that part of the discussion relating to entomological illustration would naturally be more instructive coming from an entomologist of wide experience than from any other source. The excellent chapter entitled "Entomological Drafting," by Professor G. F. Ferris,* of Stanford University, is recommended to students. It includes all of the essential points needed in portraying the various characteristics of insects.

There are three general methods of expression used in preparing entomological illustrations, each depending upon (1) the character of subject (amount of detail to be shown), (2) the element of expense in drawing and in reproduction, and (3) its intended use—whether as an outline text figure, a detailed text figure, or a finished plate illustration. Text figures are always drawn with pen in lines, and may include some stippling. The two

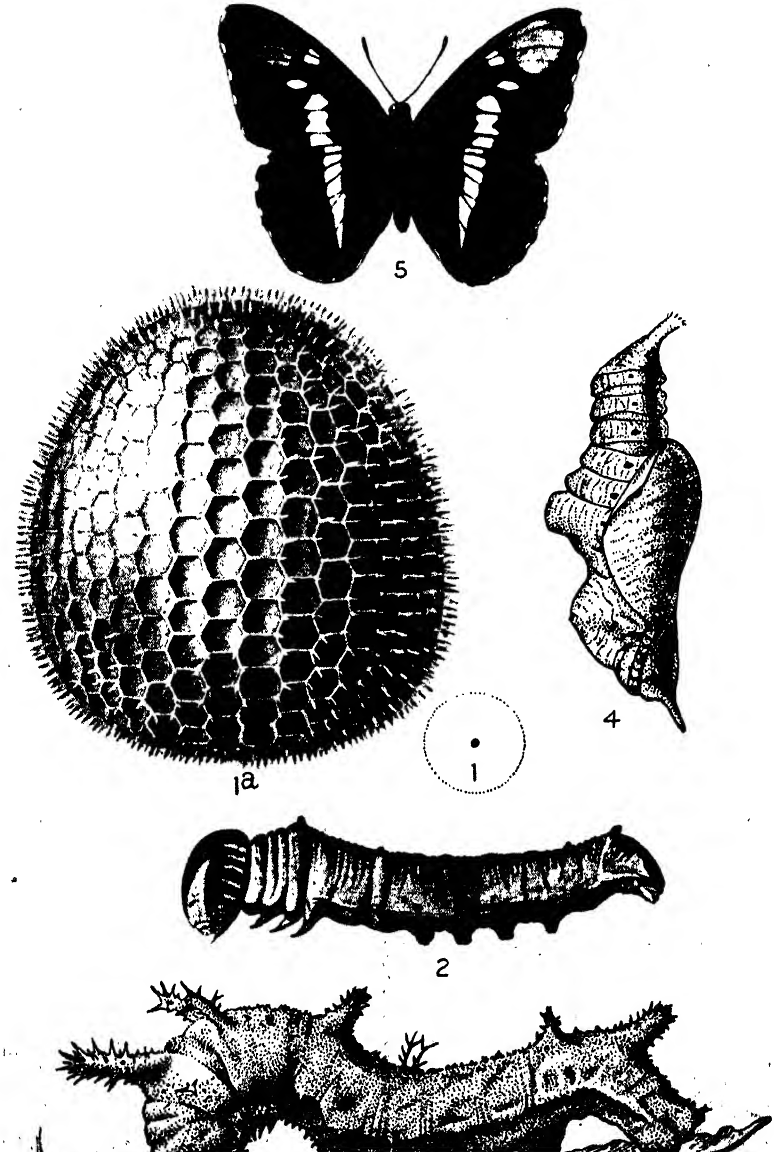
* Gordon Floyd Ferris, "Entomological Drafting," *The Principles of Systematic Entomology*, Stanford University Press, 1928.

PLATE VI

Half-tone reproduction, Guadaloupe House Finch, showing subordinated accessories

(See p. 44)

PLATE VII



Illustrations of a complete metamorphosis of a common butterfly (*Heterochroa bredowii californica*): 1, Egg, natural size; 1*a*, egg, highly magnified; 2, newly hatched larva (first instar); 3, mature larva (last instar); 4, pupa or chrysalis, lateral view; 5, imago, superior surface. (See p. 44.)

kinds of figures just referred to differ only in the amount of detail and character the drawings are to include. These methods consume a minimum of time in preparation, and their reproduction is least expensive of all the processes.

Finished plate illustrations are always more elaborate, depending upon the subject and the mode of presentation. In making such drawings the artistic element in the work combined with superlative accuracy—a sometimes difficult combination—is generally required. The cost of illustrations of this kind is much greater than in the line drawing, both in preparation and in reproduction, especially if colors are used (Plate VII).

Line drawing in its various degrees of development of detail is, therefore, much more liberally used by entomologists than the more elaborate methods such as brush-and-color drawing, by reason of its simplicity, its direct illustrative force, and its relative cheapness.

Because of the generally imperfect condition of cabinet specimens, it is customary to prepare first of all a preliminary pencil drawing. If a camera lucida is used in making the sketch, or if a direct drawing is made, it will not be necessary to draw both sides of the body. One completed side can easily be transferred (see §41) to the other side and proper adjustment can be made to complete the entire figure by giving careful attention to the median line and the natural thickness or fullness of the thorax and abdomen.

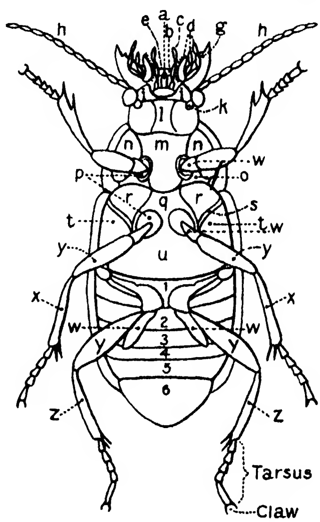


FIG. 5.—External anatomy of a beetle (under side), from *Common British Beetles*, by C. A. Hall: *a*, Ligula; *b*, paraglossus; *c*, labial palp; *d*, lower jaw; *e*, upper lip; *g*, jaw or mandible; *h*, antennae; *i*, mentum or chin; *k*, buccal fissure; *l*, gula; *m*, prosternum; *n*, prosternal episternum; *o*, prosternal epimeron; *p*, coxae; *q*, mesosternum; *r*, mesosternal episternum; *s*, mesosternal epimeron; *t*, metasternal episternum; *u*, metasternum; *v*, metasternal epimeron; *w*, trochanters; 1–6, segments of abdomen; *y*, femur; *z*, tibia.

In view of the amount of labor involved in drawing both sides of an insect, any method that can be adopted that will save

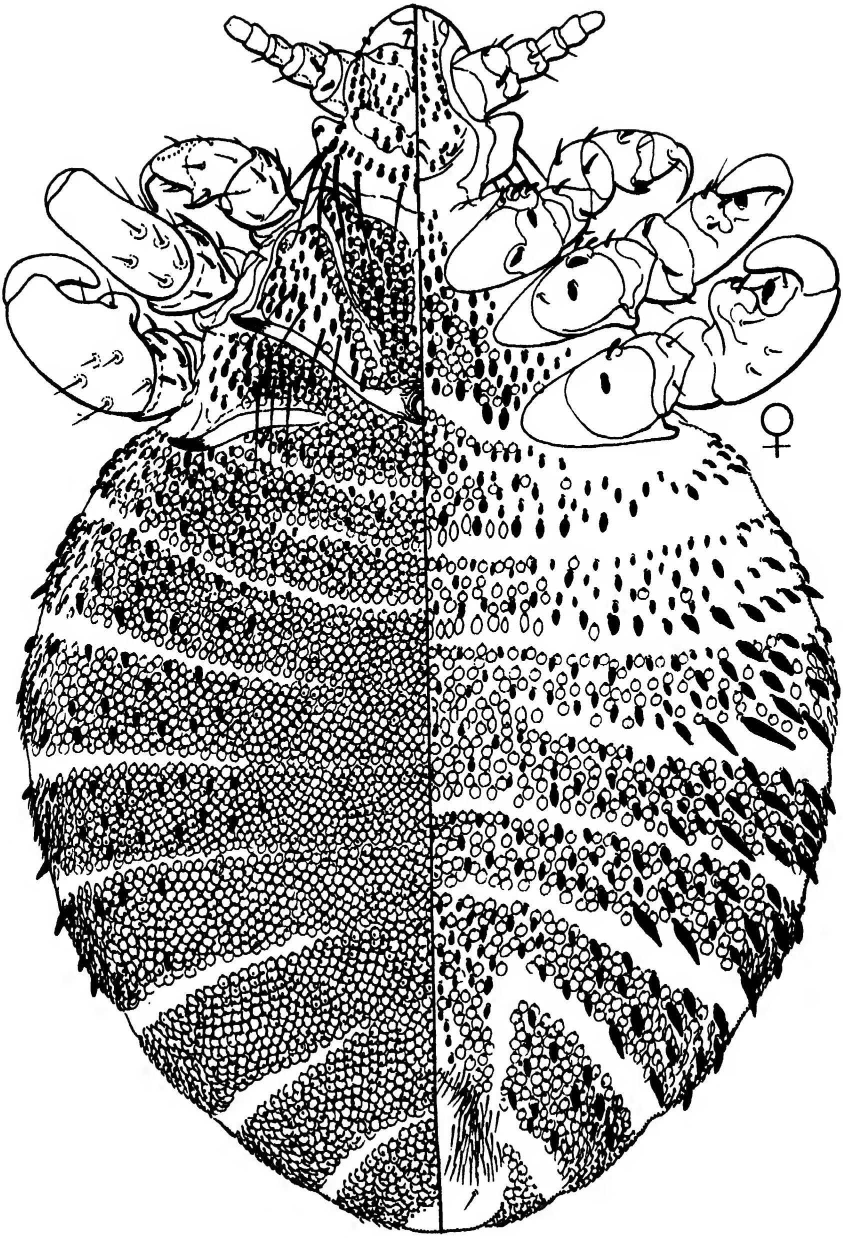


Fig. 6.—The divided drawing, illustrating *Antarctophthirus ogmorphini*, by G. F. Ferris.

time and yet preserve natural conditions is legitimate. This has given rise to what has been termed by Professor Ferris the "divided drawing." In the article cited he says:

> Such drawings are made possible by the fact that insects are at least theoretically bilaterally symmetrical objects. Actually they are probably never so. Nevertheless, the departures from the theoretical condition are so slight that they do not at all preclude the use of these drawings. . . . . So, if the right and left halves are simply mirror images of each other, all the essential requirements are fulfilled if only one half be figured.

Figure 6 presents the dorsal and ventral sides of *Antarctophthirus ogmorphini.* It took the artist much valuable time to draw this figure, and to have drawn both halves of each side, which are practically repetitions of each other, would have almost doubled the labor without any equivalent gain in usefulness. Professor Ferris continues:

> The virtues of simplicity are frequently overlooked. Consequently there is a very strong tendency among illustrators to produce drawings that are unduly elaborate, and the possibilities of the simple outline drawing are commonly not recognized. Yet, in all probability, about ninety per cent of all the work that the average entomological illustrator has to do can be presented in the form of plain outline drawings or some very slight modification of them.

This does not mean that artistic work is not sometimes amply justified. In many subjects, completeness of detail and the expression of depth, thickness, or rotundity are useful in addition to the mere representation of superficial detail. In many cases these effects can be obtained in outline drawings by careful attention to the setae and similar structures.

Photography as applied to entomological illustration has not proved entirely satisfactory, because of differences in depth of focus which fail to show all of the usual complicated structures with equal clearness. It affords, however, a direct saving in cost over drawing when it can be used for the complete figuring of a specimen or of a detail, whether under considerable magnification or not. With skillful retouching, however, many photographs not directly usable can be made to show every detail with all of their photographic accuracy. (See §20.)

For special purposes—for example, to illustrate fully the

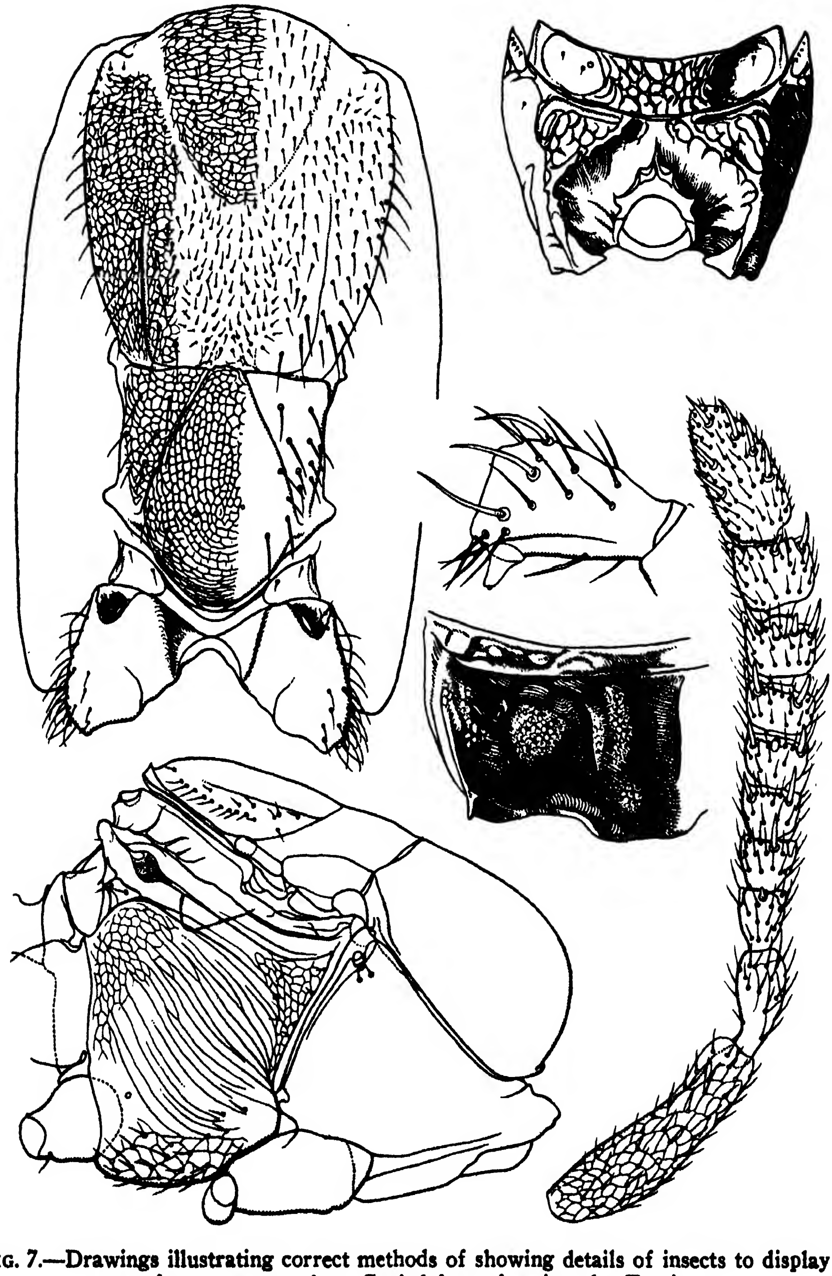


FIG. 7.—Drawings illustrating correct methods of showing details of insects to display surface ornamentation. Copied from drawings by Terzi.

general form and aspect of a species, and for plate illustrations —photography has a marked superiority over drawings made with pen or brush, unless the drawings are prepared with superlative accuracy and by one possessing the necessary artistic ability. But, as previously stated, pen-and-ink drawings are most favorably considered by entomologists generally. A good example of this class of work is shown in Figure 7, copied from one of Terzi's drawings.

Photomicrography as applied to entomology.—Most systematic workers develop their own technique in obtaining photomicrographic detail. Probably no two work alike. It is therefore deemed of value to quote the technique used by one distinguished technical worker* in the field of Lepidoptera:

Many of the objects requiring to be illustrated by the entomologist are of such a size and shape as to require special technique for their reproduction. As an example, many insects measuring approximately one millimeter in length will include structures of great importance both at the apex of the body, and the termination of the legs. These two points cannot be brought into the same focal plane in a microscope, hence the usual type of micro-photographic procedure is not adapted to their photographic reproduction. It has been our experience that such objects are best handled by the use of a special 48 mm. micro-Tessar lens, adapted to a 3½ × 4¼ Graflex camera.

Another important point is the question of proper lighting of an object. Strong light from one side only usually burns out the detail on the side of the highlight and blots out features on the side of the shadows. To overcome this, a white paper cone or short tube is placed around the subject. The light is then thrown from the side at a slight downward angle, and there is thus sufficient diffusion to bring out the essential detail, but with *enough* side light to give modeling to the object.

As already stated, pen-and-ink drawings are now more often used than photographs. They can be reproduced either as single text figures, combined into groups, or grouped into plates. They are drawn in full clear outlines and, when needed, with stipple shading. It should also be noted that all outline pen drawings are best shown with the lines thickened on the shaded side. This is well shown in the upper portion of Figure 6. Stipple shading involves less confusion with the lines of the exterior anatomy, with pigmentation, and other superficial details when present,

* Dr. John A. Comstock, of the Los Angeles Museum.

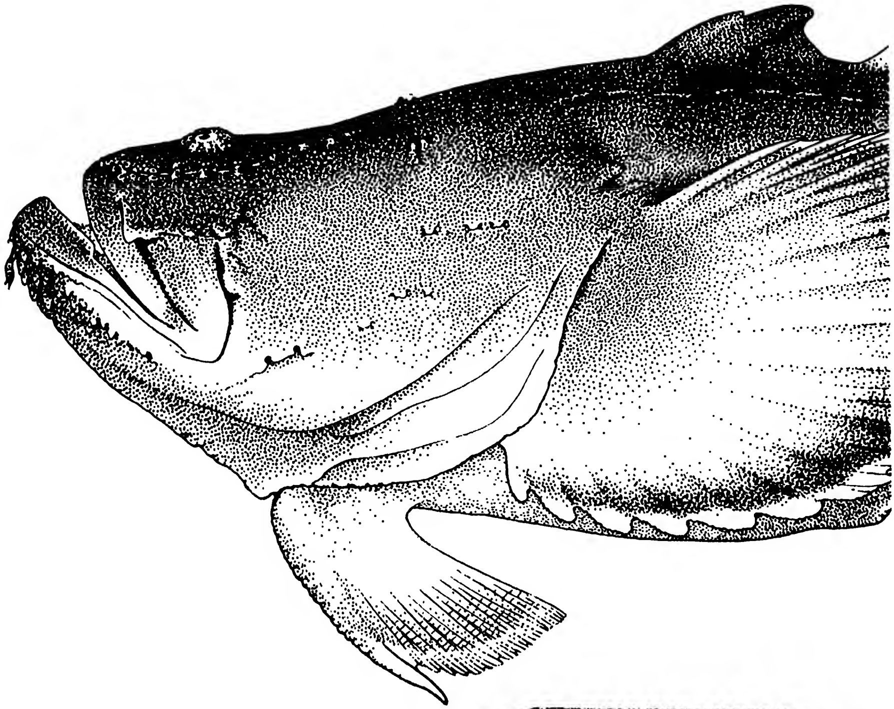
especially those that must be represented by pen lines. Such drawings can also be made on Ben Day or similar board, selecting a pattern composed of either fine stipples or lines. The lines or other pattern appearing on the board can be made to supply a ground tone upon which the shading (if needed) and details are added. Highlights and the area surrounding each figure can be scraped away so that the figure will appear on a white ground. This is a cheaper method of drawing and is useful in the preparation of the simpler kinds of subjects in any field of science.

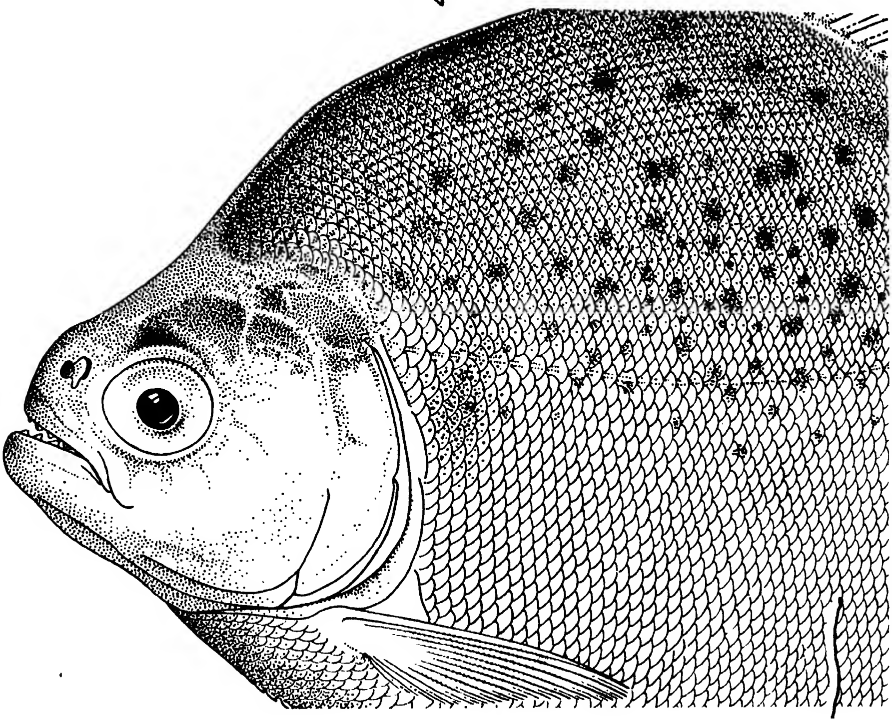
Ichthyology.—A finished fish drawing probably represents more real work per square inch of surface than any other kind of drawing except possibly other scaled vertebrates, for the reason that scales and other surface details must be carefully worked out and developed, and not be merely sketched in to show general effect. It is therefore necessary that a carefully prepared pencil drawing be made as preliminary to the final drawing. To do this intelligently the draftsman should be conversant with the exterior anatomy of fishes. This information is easily obtained from textbooks. He should know that there are four separately distinguishable parts of the body of a fish—the head, trunk, tail, and fins. In these principal parts it has been said that there is probably greater variation among the fishes than among any other class of vertebrates.

It would be impossible to describe except in very general terms the technique used in drawing fishes. As with all other kinds of specialized work, its successful accomplishment will depend first of all upon some native ability. The would-be ichthyological draftsman must know how to draw good clear, sharp lines and well-spaced stippling; then by studying the best technique of others, just as the scientist must know what has been done before him, he can adopt the technique required for the kind of subject in hand.

There are two generally distinct methods of drawing fish. One, the most universally used, is the pen-and-ink drawing, of which there are two distinct kinds—the outline drawing and the completely finished and shaded drawing. (See Plate VIII.)

PLATE VIII





The other is the brush, or brush-and-color drawing. They are distinct methods partly because expertness in one does not always cover expertness in the other.

The beautiful stippling and scale work shown in the original drawing of Plate VIII, equally well shown in the cut, represent the acme of execution in this branch of scientific illustration. The use of this plate here demonstrates the greater service of an illustration over word description, for in the plate the story of precision and proper technique used in its several parts is far better told than could possibly be imparted in any other manner. The plate is offered as an aid in taking up the drawing of fishes. Attention is called to the regularity of the stipples and the carefully planned arrangement of the scales. The complete drawings could not be included on account of the small size of the text page in this book. The originals were prepared by Mrs. Chloe Leslie Starks, of Stanford University.

The other kind of drawing is the finished portraiture made in washes of lampblack, India ink, or sepia, or in colors. This class of work always requires artistic treatment.

§19. Color Work and Colors

To illustrate an object in color one must be familiar with all the rules that prevail in other kinds of drawing and must observe many additional principles governing the technique of color drawing and painting. One in particular is color reflection, by which a local color may be considerably modified by reflection from surrounding objects near or far.

This is exemplified most strongly in the reflection of the sky and surrounding objects on still water. Water has no color. Reflection is present, however, everywhere. It comes from the walls and the ceiling, from windows, and from other objects and masses both in and out of doors. In making a drawing in color these reflected lights and colors need careful study.

Then again, every color has its own shade—not merely one produced by the addition of a black or a darker pigment, but a shade peculiarly its own. For example, the proper shadow for a pure white object is a neutral tone produced by the admixture

(in proper proportions) of three primary colors—red, blue, and yellow. A shadow of proper hue will not change the visual effect of a colored object under any kind of lighting, whereas if the shade is not of the correct hue the general color of the object is falsified. The term *local color* is used to express the real color of an object, since most objects are partly in shadow and partly in illumination, neither of which is the true or local color. These, and many other principles in color drawing and painting, will be better understood by the beginner as he finds them by practice and experience.

The preliminary pencil drawing of a specimen or object to be made in color is not unlike those to be finished in washes or by pencil or pen. Practically the same methods are used up to the point where the pencil is laid aside and brush and color are taken up. The paper used should be of a quality suited to the kind of subject to be illustrated. For very small and minute forms, in which delicate gradations of color and minute details are shown, Bristol board of the quality of Reynolds' 3- or 4-ply is recommended. The smoothness of this board aids in the delineation of the smaller details and in the smooth blending of colors. For larger work Whatman's Hot-Pressed drawing paper and that commonly known as "illustration board" are recommended. Most papers on sale at art stores and recommended for use in color work will be found more or less satisfactory. Strathmore Drawing Board is well suited for large work up to 20 × 30 inches, but it is not so suitable for small drawings, on account of the slightly roughened surface produced by erasures.

The colors recommended are Winsor & Newton's water colors in full or half pans. This does not preclude the use of other water colors on the market, many of which have been found to be perfectly satisfactory. A good working set of colors for use in scientific illustration is named in the following list, which includes colors not often used on account of their brilliancy. There may and often will be needed a pigment expressing a color not included in the set, or one that cannot be produced by admixture. In a case of this kind it sometimes becomes necessary to call into use other colors generally named

in catalogues. This difficulty sometimes confronts one in making drawings in color of birds, insects, and botanical specimens for which pure, unmodified, or unbroken colors are often needed; but it should be remembered that the local color usually shows pure in only a small part of an area. The rest is either in shadow or is illuminated.

Crimson lake	Olive green
Orange vermilion	Hooker's green No. 1 and No. 2
Mauve	Emerald green
Burnt sienna	Payne's gray
Sepia	Cerulean blue
Cadmium yellow	Prussian blue
Chrome yellow	Lamp black
Yellow ochre	Chinese white

For all scientific work water colors are preferred and are generally used. There is no general formula for mixing and modifying colors, but, by careful visual analysis and by experience, one can learn how the various color hues, shades, and tints in nature can be copied. Only the spectrum shows the three fundamentally pure colors, red, blue, and yellow; and the best pigments representing these colors are only approximately pure. When these three colors are placed in a circle—red grading into blue, blue into yellow, yellow back into red—the overlapping and combining of these colors produces purple, green, and orange, respectively; and these are the secondary colors. The combination of the secondaries in the same order produces hues generally undetermined as to name unless compared with standard color charts.

Thus it will be seen that the combination of a red and blue pigment will produce purple; blue and yellow will produce green; yellow and red will produce orange. When one color predominates, as for example red over blue, the result is a reddish purple; and when blue predominates over red the result is a bluish purple or violet. But these combinations refer only to the spectrum colors. All other colors are called impure or *broken* because they do not occur in the solar spectrum. They represent an almost infinite variety of the color hues, shades, and tints found in nature, and not only contain the elements of the spec-

trum colors already mentioned but have in their composition added black and white pigments—black representing the total absence of color by complete absorption, while white is the refraction of all the colors of the spectrum—and in painting they may be regarded as absent.

Therefore, to match any of the impure or broken colors one must have, first of all, acute color appreciation which will carry with it an ability to discriminate colors closely and to select the pigments that will best represent them in combination. A well-trained eye can detect the prime colors which, in some kind of combination, produce any of the impure or "broken" colors. For example, should it be required to match the color known as sepia, it would be found by eye analysis alone to contain red, blue, and yellow—the yellow killing the effect of purple—and by using certain percentages of each, together with the addition of a black and a white pigment, the desired color could be obtained. Thus any of the broken colors can be matched by a careful visual analysis of the elements of color they contain.

An excellent way to master the technique of matching colors is to copy pictures, selecting first the simpler kinds, studying their color effects, lights, and shadows, just as if they were shown in a real object. The work should be done slowly and every effect should be carefully copied with a view to knowing how it may be obtained.

§20. Retouching Photographs of Specimens

Photographs of specimens are retouched not always because the prints are poor photographically but often because they fail to show important features clearly. This is most often true in photographs of small forms. In fact, applied to specimen work generally photography often fails to produce an even development of every part. It is liable not only to accentuate parts not needed, including cracks and other imperfections, but also to stress differences in local color. The latter difficulty is not so apparent in photographs of fossils that have been coated to destroy stains or differences in color. This method of coating specimens to make them uniform in color before photographing

was first used and patented by the late Professor H. S. Williams, of Yale University. His original method has since undergone some minor changes. The "Williams process," as it was called, was described as a method of coating specimens by sublimation of ammonium chloride. This is still the basis of the process, but it is now accomplished in various ways designed to simplify the work.

Prints needed for specimen work should be on unglazed, mat-surfaced paper, printed in a tone slightly lighter than that of a normal or ordinary photograph. Papers known as "Azo A" single weight and "Velox" are now much used for specimen work. The details and relief in such prints should, however, be strong enough to enable the artist to see them definitely, so that after strengthening of the shadows and details the figures will appear sufficiently strong for reproduction. This can sometimes be done by a combination of pencil and brush work, but the brush must be used sparingly for the darker parts only, using a No. 2 or even smaller Winsor & Newton's red-sable brush and lampblack. Pencils of the grades of B, F, 4H, and 6H are used for retouching details and in producing the necessary gradation in shading. All the retouching should be done under a reading glass to insure accuracy and aid in producing the soft effects of the photograph. In having hand specimens photographed, if the backgrounds are to appear white, the ground tint or background surrounding each figure should be carefully opaqued or painted out. Some photographers pose their specimens on a glass plate under which light is reflected so as to produce an opaque film on the negative around the specimen. If a black background is desired (and in minute forms it is effective), the exposure should be made with that intention.

In retouching photographs of the smaller or microscopic specimens, the lights and shadows will sometimes need altering in order to make them agree with the proper system of illumination. It is therefore necessary to compare every part of the photograph with the specimen and, if necessary, to lighten the darker parts and develop details in those parts in which the illumination or the shadows have destroyed them. Highlights

may be strengthened or added by very gently scraping the surface with a very sharp penknife; but it should be borne in mind that the sensitized film on a print is exceedingly thin and scraping below it will occasion an irreparable blemish. Sometimes powdered pumice is useful in lightening parts. All general erasures are made with a hard rubber that is free from sand, or by very gently scraping the surface.

An important part of a retoucher's equipment should be a quantity of Plasteline or modeler's clay upon which the harder specimens may be posed. This may be obtained in most art stores.

As stated, the greater part of retouching a smooth unglazed print is done with pencils. The point of each pencil should be kept very sharp by occasionally rubbing it on a sand block. Good effects in strengthening very fine details are often obtained by first using a soft B pencil very lightly and tracing over it with a finely pointed, very hard pencil. To prevent or reduce to a minimum the gloss produced by the pencil, never give it force or weight. Always use a pencil with light pressure.

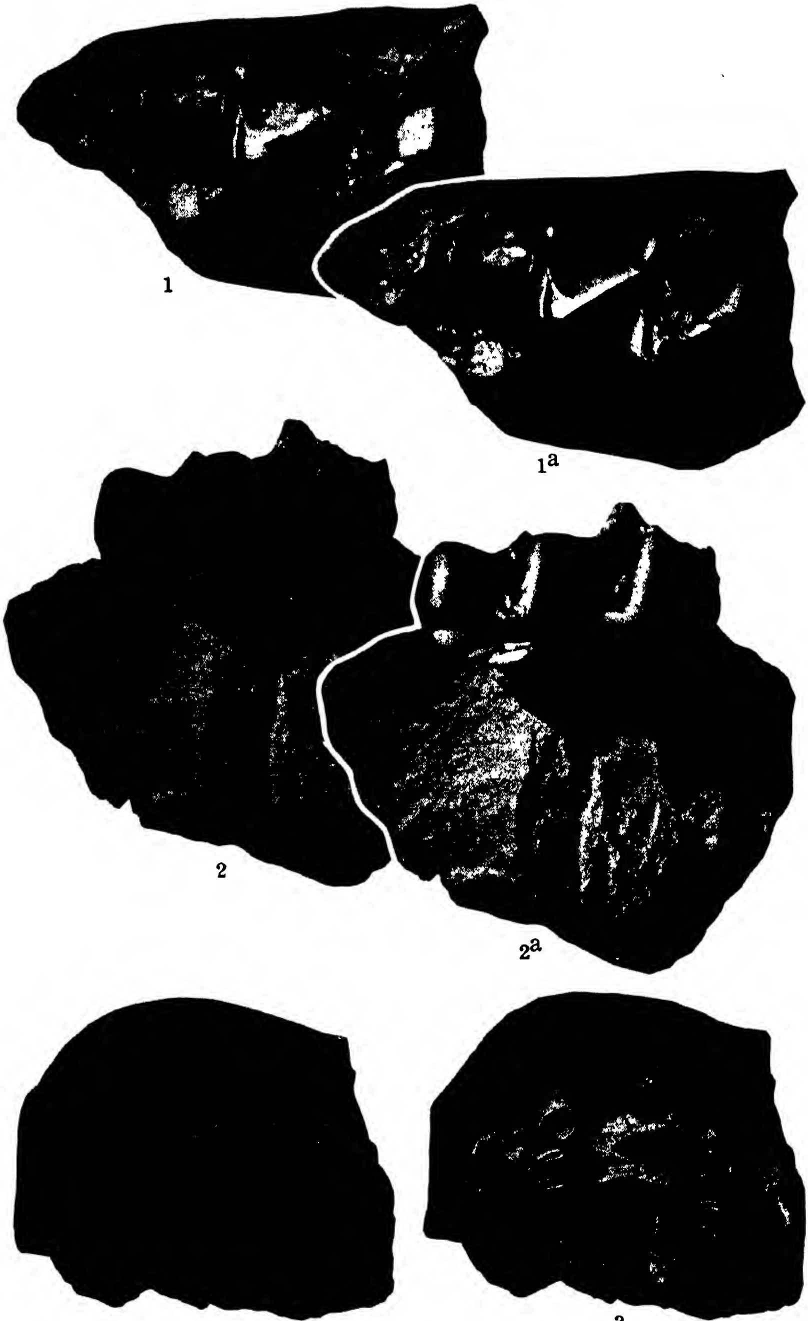
Plate IX shows a group of retouched photographs, and the original untouched prints for comparison. These figures were retouched with pencils, and show how the salient features of a photograph can be brought out without producing unnatural effects.

The custom followed by some museums and collectors, of varnishing or shellacking specimens—probably to prevent further disintegration—makes the retouching of photographs made from them particularly difficult. The highlights caused by the light rays striking directly on irregular surfaces produces effects that are not only confusing but often misleading. In retouching such photographs, highlights other than those properly showing the real form of the object should be subdued before beginning the real retouching of the specimen.

§21. Retouching Outdoor Photographs

The kind of outdoor photograph most suitable for retouching is one on a smooth, unglazed paper having what is known

PLATE IX



1 1a 2 2a 3 3a

Photographs showing, by comparison with originals, the improvement gained in retouching. Figures 1, 2, and 3 are the original prints. (See page 56.)

as a "mat" surface, and printed in a slightly lighter tone than normal. Such paper as Velox or Azo A, either single or double weight, will be found to be suitable. Glossy prints cannot generally be retouched successfully unless an opaque pigment is used; but it is sometimes possible to improve a glossy print greatly after carefully rubbing the surface of the print with powdered pumice. This tends to kill the gloss and give a surface upon which the penciling will adhere sufficiently to strengthen some of the fainter tones and details.

Outdoor photographs often show such defects as bad skies, faint or foggy distance, black shadows in which there is no development of detail, and a general lack of sharpness in other parts. In order to remedy these defects the artist doing the work should be able to supply natural effects in a manner corresponding with those shown in the photograph. If the photograph is unglazed, the retouching may be accomplished with pencil as described in the preceding subject; but if the photograph is of the glossy variety and needs elaborate retouching, the artist should provide himself with a jar of the best Chinese or other white, a color-box containing Indian red, yellow ochre, ultramarine, and lampblack—colors with which he can duplicate the tones in any photograph by admixture with white. He should also have the best grade of red-sable brushes ranging in size from No. 2 to No. 8, a stack of porcelain saucers, and a jar of oxgall, the latter being used as a flux for causing the pigment to adhere to the glossy print. By mixing the colors to match the tone of the photograph exactly, he can retouch parts and cover imperfections so that they will not show in reproduction.

It should be understood that in this method of retouching photographs, the mixture of white with other colors produces an opaque pigment or "gouache," and that in matching tones on a photograph the pigment changes its tone in drying. Opaque pigment is used in the airbrush.

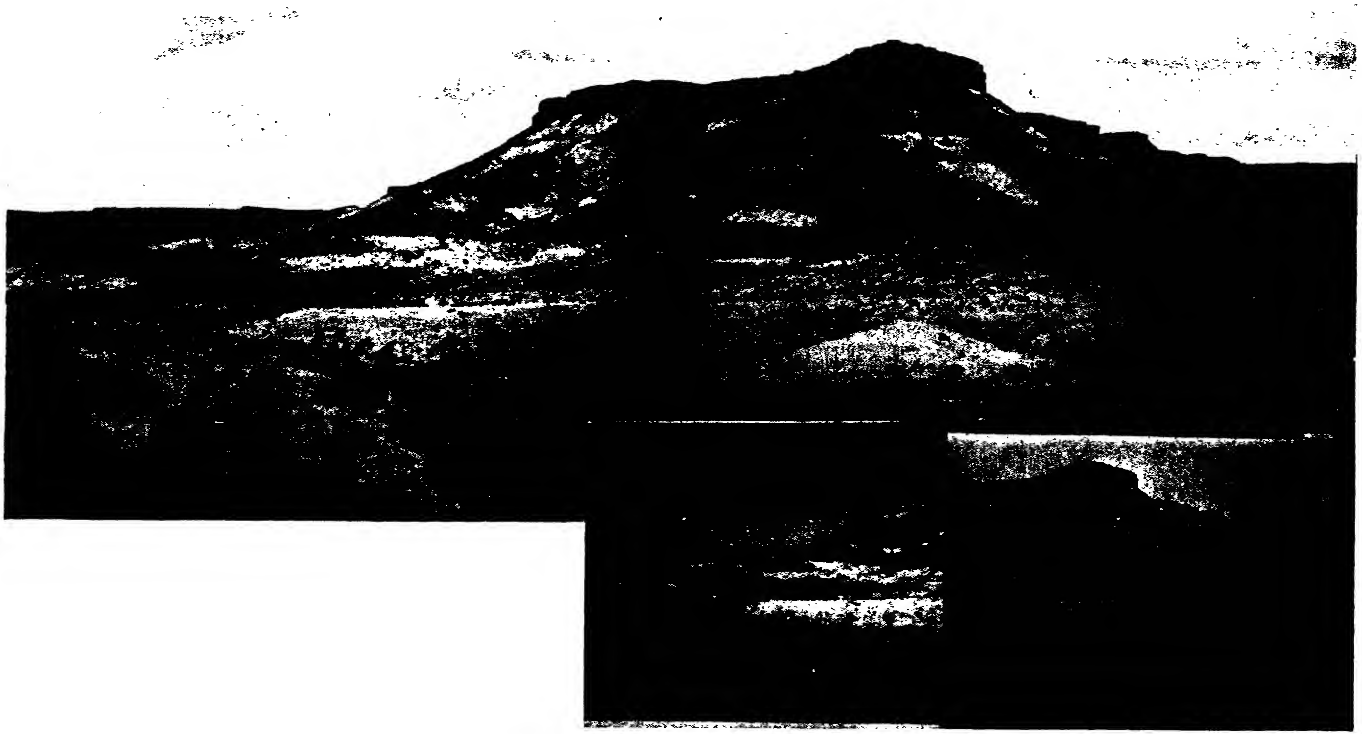
Airbrush or air gun.—For the purpose of adding new skies and covering large areas in either a glossy or an unglazed photograph, an airbrush outfit, including a compressed-air tank

with either an electric motor or pedal action, has been found to be indispensable. Those manufactured by Thayer & Chandler, Chicago, are recommended. In addition to its applicability for retouching photographs, the airbrush has other uses in supplying softly graded tones in making drawings. It has not, however, been used to any great extent in scientific illustrating, since a sufficient delicacy in tone effects can generally be produced with ordinary red-sable brushes and India ink, sepia, or lampblack. The airbrush has been and is much used in commercial work, in making drawings of tools and machinery, as well as many other kinds of drawings to illustrate catalogues and advertising matter. While it supplies effects to relatively large areas in a way superior to ordinary brush work, its adoption in preparing drawings to be used for scientific purposes has not proved to be of any great advantage.

In using the airbrush for retouching photographs, a color made up of Chinese white as a base, to which one or more other colors already referred to have been added in order to make the retouching pigment match exactly the tones of the photograph, is sprayed on the surface of the print in the form of vapor, as the artist desires. The parts which are to be protected from the spray are covered with liquid rubber spread on with a brush. The liquid rubber dries quickly by evaporation and can readily be removed after the operation, leaving the parts so protected clean and in perfect condition. Sometimes masks of paper and other substances are used for the same purpose. As stated, the airbrush is used primarily to cover the larger areas, and these may be further developed by hand work.

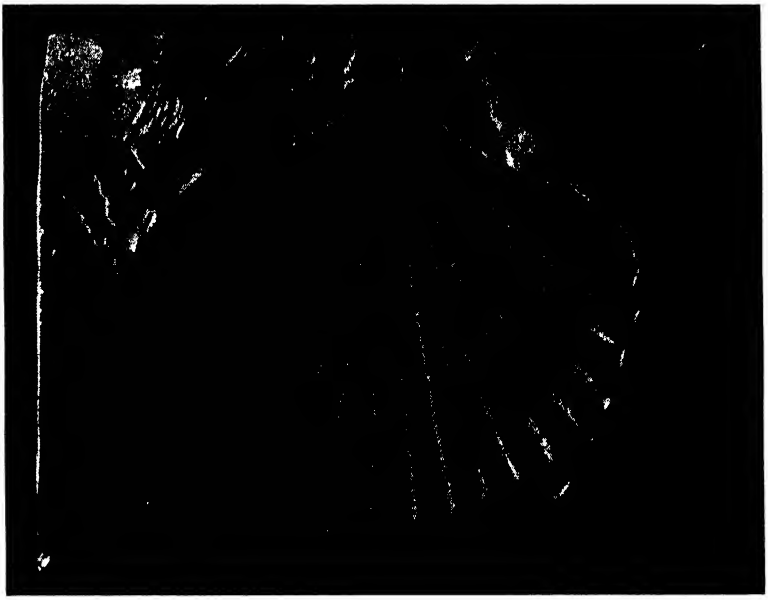
One of the impossibilities in retouching photographs is covering cracks, tears, and other injuries found in a print. Sometimes there is occasion for joining photographs in the form of a panorama. In all such work the joined photographs and those that are damaged should be rephotographed in order to obtain a new print of the whole on one piece of paper. Such a print should be made on unglazed Velox or Azo paper, single weight, and if the sky is uneven or otherwise unsatisfactory it can be opaqued on the negative before the print is made so that

PLATE X



Halftone cut showing, by comparison with original photograph (insert), the improvement gained in retouching. (See page 59.)

PLATE XI



A. Photograph of impression or mould. Cf. *B*, below. (See page 59.)

B. Positive aspect obtained from mould, *A*.

the new print will show that area white; or it may be sprayed on with the airbrush. A cloud effect can also be added if desired. When it is desirable to increase the width or depth of photographs placed in panoramic form, the photographer should be instructed to furnish prints on paper wider than the negative, upon which the pictorial effect of the foreground may be extended downward, increasing the depth of the picture. Similarly, the sky may be extended upward to increase its height.

A photograph properly retouched should give very little if any artificial effect. It is a kind of work that should be done, if done well, by one capable of making an acceptable drawing of a landscape or other subject with approximately the softness and delicacy of a photograph.

Comparison of a retouched outdoor photograph with the same print as it appeared before retouching (though reduced in size) is shown in Plate X. The print was made on Azo A paper, and the retouching was done entirely with pencils.

Fossil moulds or impressions.—When only the impression or mould of a fossil has been preserved in a matrix it can be successfully figured in its positive aspect by photography. Plate XI illustrates the result of a method by which the relief instead of depression of such a specimen can be shown in some instances, with almost complete detail. In preparing Plate XI, a plaster mould of a shell was made and turned over to an experienced photographer.* His description of the method adopted in obtaining the required result follows:

> Proceed as usual photographically, with these exceptions: Substitute a suitable bromide paper for the film or plate in your plateholder, and light the subject from the right-hand side. Having developed the bromide paper, which is in reality a negative on paper, you have the desired relief, and if technically correct the bromide negative itself serves as the print.

A similar result could have been obtained by simply reversing the negative film when printing, but the right and left sides of the figure would be in reverse of natural.

* The late Mr. H. William Menke, of the Los Angeles Museum.

One of the most noteworthy occurrences of this kind of preservation is in the Lompoc diatomaceous shales in which many skeletal remains of birds and fishes are found. Numerous illustrations from this formation, treated as stated in the first place, and photographed by Mr. L. E. Wyman for the present writer, will be found in *Avian Remains from the Miocene of Lompoc, California* by Dr. Loye E. Miller.† The Lompoc material cleaves along old bedding planes and in many instances reveals the partially carbonized bones imbedded in the matrix, which separates freely from the bones, thus leaving, generally, a satisfactory impression of the original bone.

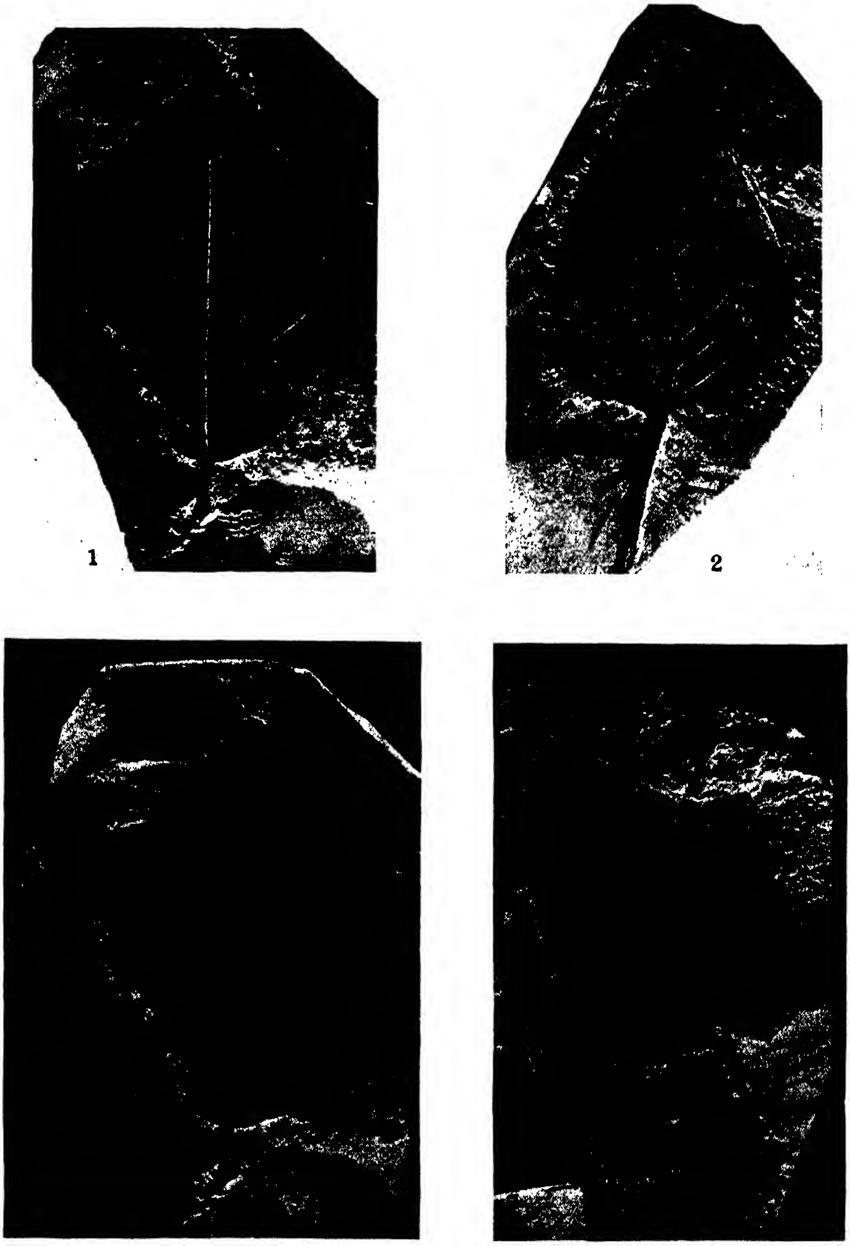
Since in many localities and in various kinds of sediments similar impressions are found, it is often desirable to figure them. Satisfactory results may be obtained, as will be seen in the publication cited, and in Plate XI in this book, by good photography combined with proper artistic manipulation of the print. In accomplishing the latter part of the work, the intervening or nonessential areas in the matrix should be cleared of distracting details by eliminating all strong shadow effects, especially those caused by irregular or angular fractures. Their removal not only will simplify the illustration as a whole but will give greater emphasis to the figures.

Fossil leaves. — In paleobotany the retouching of photographs of fossil leaves is always an essential step toward a clear presentation of details. It should be understood that a slight loss of definition may always be expected in a photographic reproduction by any process, and it is partly to compensate for that loss and to preserve original detail that the retouching of fossil leaves is done. While the nervation will appear stronger after retouching than in the specimen, its strengthening (if done with great care) will not misrepresent or falsify those features as they were in life.

The first requirement in retouching fossil leaves is that all photographs be printed on a smooth, mat-surfaced paper, that known commercially as "Azo A," single weight, having been used successfully. The paper should be a smooth, unglazed

† Publication No. 349, Carnegie Institution of Washington, pp. 107–17.

PLATE XII



Fossil leaves before and after retouching. Nos. 1 and 2 retouched; Nos. 3 and 4, same photographs before retouching. Specimens, courtesy of Dr. Ralph W. Chaney, University of California.

stock. Should the photographs need no retouching, a glossy print is sometimes preferable. If possible the photographer should furnish two prints from each negative—one normal in strength, the other slightly lighter.

In proceeding with the retouching the first step should be to simplify the effect of the picture by eliminating all strong shadows in the matrix surrounding the specimen. This may be done with a very sharp penknife by very delicately scraping off the surface of the print at those parts without destroying the character of the rock. This will often leave white patches on the film which may then be restored to the local color of the photograph by a B or F pencil used with light pressure or with brush and lampblack.

Sometimes the impression of a leaf may be stained by oxidation in such a way as to produce photographic variations in color and other misleading effects. Such defects may be treated successfully by very careful scraping or by rubbing powdered pumice over the areas so that the essential details, often very faintly shown, will not be disturbed.

After treatment as just indicated, the work of strengthening the nervation should proceed, using generally a B pencil sharpened on a sand block to a long, fine point and further pointed on a fairly rough-surfaced paper. As already stated, the thin line produced with the B pencil can be intensified by tracing over it with a hard pencil, finely pointed. Especial attention should be given to all marginal character, and the restoration of broken parts should not be attempted unless requested by an author. Strengthening the nervation should begin with the midrib or primary nerve, then the secondary, next the tertiary, and, if possible, the continuation of these nerves to the margin. No guesswork should be attempted, since the purpose of retouching is only to produce a "copy" which when reproduced will show with greater clearness all the faintly defined details of the specimen.

The finished work should be enclosed in a penciled rectangle, squared by the primary axis of the leaf to guide the author in cutting out the part to be reproduced. (See Plate XII.)

It is also recommended that the solid black parts of the photograph be cut out of the picture. They mean nothing and should be eliminated. If desirable, the completed pencil rectangle can be shown in order to square the cut. If this is done, a flat half-tone tint will replace the black mass.

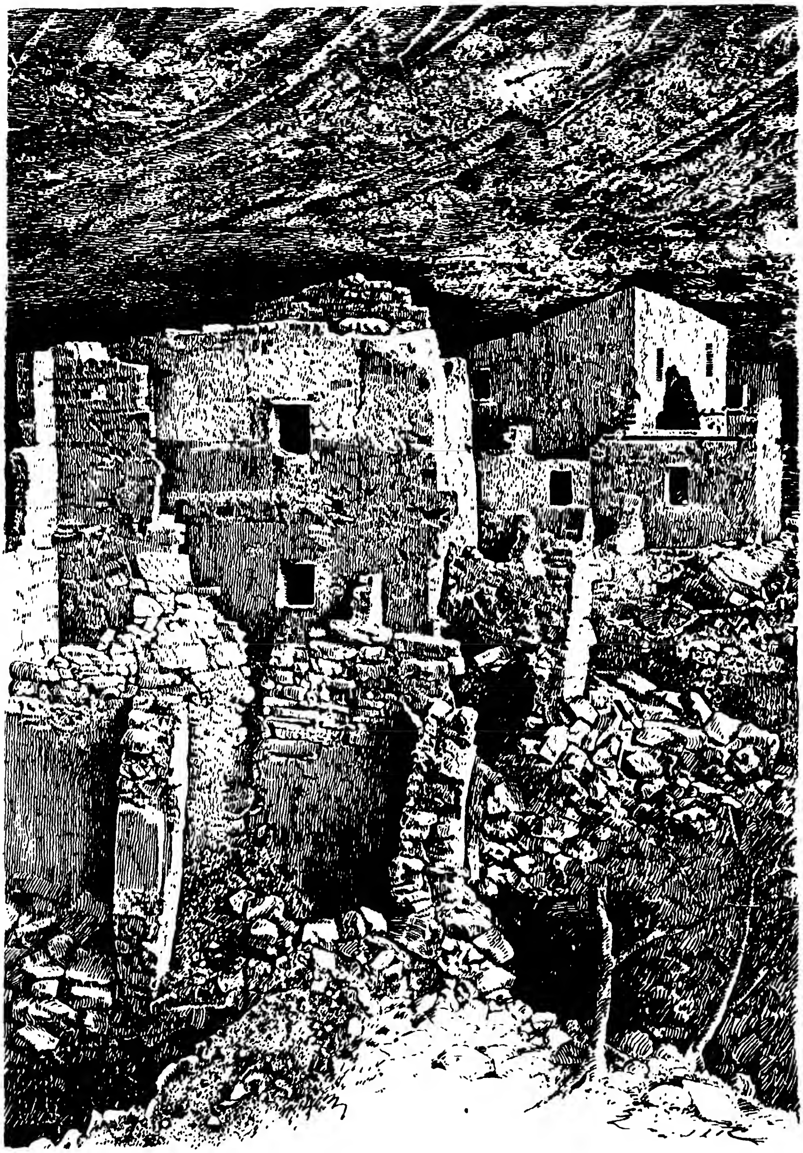
§22. Pen Drawings Made over Unsatisfactory Photographs

It very often happens that an author has just the photograph he needs but finds the print not sufficiently clear for reproduction. In a case of this kind, or in case the photograph has been injured and cannot be retouched, an acceptable illustration can always be obtained from it by having it rephotographed, making a pen drawing over the new print, and then bleaching the print. An enlarged bromide print or a blue print may be treated in the same way. The features desired on such a photograph are traced with waterproof India ink, the amount and character of detail to be copied depending upon requirements. It may be merely a sketch in outline or it may be a completely finished drawing. Such drawings (after bleaching) are reproduced by zinc etching. Plate XIII was made over an enlarged bromide print and bleached. Any kind of subject may be treated in this manner.

The print should be larger than publication size and should not be so dark that the draftsman cannot see his ink lines. For that reason blueprints are generally preferred. If the negative is available, a bromide enlargement can be obtained. The enlargement will give the artist greater freedom in drawing details and will make his work appear finer and better in the reduced illustration. If the photographic print is of a subject requiring the use of instruments, it should be securely fastened to a drawing board, square with the board, so that any horizontal and vertical lines in it may be ruled by the use of a T square and triangle. For specimen or landscape work it need not be fastened.

Bleaching prints.—For bleaching blueprints a saturated solution of oxalate of potassium ($K_2C_2O_4 + H_2O$) has been used with good results. For bleaching bromide prints, cyanide

PLATE XIII



Pen drawing of ancient cliff dwelling, made over blueprint and the photograph bleached out and dissipated. (See page 62.)

of potassium (KCN) to which a few drops or flakes of iodine have been added can be used. Neither kind of print should be bleached until the drawing has been completely finished in every detail, because bleaching loosens the fibers of the paper, so that making corrections or additions, if needed, is difficult. The print should be placed in a hard-rubber pan, the bleaching solution poured on it, and the pan rocked until the image disappears. The print should then be carefully removed, thoroughly washed in running water, dried, and finally mounted on cardboard. For temporary, hurried work on drawings that are not to be retained for future use a blueprint may be mounted first and bleached by pouring the bleaching fluid over the mounted print.

For bleaching prints made on Velox, Azo, or other brands of paper proper chemicals and full instructions can always be obtained at photographic supply stores.

The character and artistic effect of such drawings will, as a matter of course, depend upon the artistic skill of the draftsman; but one who can make an original pen sketch good enough for reproduction will find no difficulty in producing a bleached drawing with practically photographic accuracy.

§23. Brush Drawings Made from Unsatisfactory Photographs

Brush drawings may be made directly from photographs of any kind of subject in which the prints are defective or unsuited for reproduction (1) by working over the print with opaque color composed of Chinese white and lampblack or other pigments, and (2) by making a tracing and a complete pencil sketch of the photograph and working the sketch up with lampblack or sepia in transparent washes. The photographs should be larger than publication size when practical in order to permit greater freedom and breadth in drawing details. The larger size will also afford a more refined and better engraving when reduced. If lampblack or India ink is used in making the traced drawing and the subject is small, Bristol board is recommended; but if the photograph is larger than,

say, 8 × 10 inches, Whatman's Hot-Pressed Double Elephant, Illustration board, or similar paper, laid down with thumbtacks or dampened and pasted along the edges, will prove satisfactory.

When opaque color is used—and it may be used over a glossy print—a preliminary drawing is of course unnecessary; but the photograph should be of a size that will require some reduction, and the finished work should be protected by an oversheet. In using opaque color, oxgall will aid in causing the pigment to adhere to the polished surface of the print.

§24. Landscape or Outdoor Sketching

General requirements.—In no other class of work can there be fewer unalterable rules than in the drawing of landscapes, for in anything approaching art the individual or personal touch necessarily enters to a great extent into the character of what is produced. Therefore the simple rudiments of composition—linear and color perspective, sunlight and shadows, reflections, grouping of masses, atmospheric effects, color values and contrasts, and a few other elementary principles — are about all. The rest is technique and technique in art is individual, for no two artists work alike. The *modus operandi* up to a certain point may be much the same, but beyond that it differs just as all personalities differ. In landscape drawing the word "impression" seems in some way to dominate, for it is the broad or general impression of a scene one receives first and attempts to record that is to make the picture. Details come afterward.

It should be well understood that one cannot improve on Nature. The nearer it can be copied the better. But not all Nature is beautiful, and one must select that which appeals. So it is sometimes necessary to simplify a scene by omitting unseemly details, and possibly to rearrange parts in order to produce a man-made composition. Otherwise the nearer one can copy what is before him the better will be his picture.

Distance in landscape drawing is shown by the gradual diminution and complete loss of details. That is one of its

beauties, since upon this matter of distance depends a certain softness compared with the strength of color and detail shown in nearer parts of the picture. An impression of what one sees should not, however, be confused with "impressionism," which refers to the work of artists whose painting represents an impression of a scene exclusive of detail and in which only the position of objects and masses and the various phases of color, lights, and shadows that please are copied broadly—sometimes vaguely. Such pictures are attractive if done in a masterly way; but many examples of this so-called impressionism show its successful achievement to be far beyond the ability of the artists who made them. On the other hand, while detail tends to reduce the artistic effect of a drawing, it must be shown, sometimes vividly, in drawings made for the purpose of illustration. It should be remembered, however, that these pages treat particularly of scientific illustration, which permits the inclusion of more detail than the more popular and artistic phase of picture making.

When a drawing is made for the purpose of illustrating certain features in a landscape, the important point is to express those features with some degree of accuracy. The drawing may be done as artistically as possible, but it should be made to fulfill first of all the purpose of the illustration.

In drawing a landscape, first select from the scene the part that shows the center of interest, and use that as the dominant or focal part of the picture. Locate that feature lightly on the paper with a soft pencil, with as much adjacent scenery as will make a satisfactory composition, paying close attention to the relative size and proximity of each object or mass. Composition in picture making might be defined as a certain balance of parts often depending on individual taste; but the balance should be maintained. To produce this composition, which is the first important step in making a picture, first draw only light, "sketchy" outlines to represent each part in its true relation to the others, then correct the various parts and begin drawing with more completeness of detail. This preliminary sketch in outline is made only to aid in producing the composi-

tion which is to be the basis of the picture and from which the actual drawing is to proceed in greater detail, keeping the entire picture in development until finished. Some artists develop one feature at a time, but in this there is no hard and fast rule. The first method is recommended as being best suited for making drawings.

The art of sketching from nature is one in which few but professional artists excel. Not many scientists are able to make sketches from nature that are suitable for direct reproduction. A more skillful draftsman can, however, copy such original sketches in their true perspective and relations. In fact, any crude, unfinished sketch will generally show the important features with sufficient clearness to be followed in producing a good pen-and-ink sketch for reduction to a text figure, which would be the most appropriate form for such an illustration.

Linear perspective.—Many books on perspective have been published. The science is exhaustive, has many uses, and covers the entire field of visual perception, whether shown in the intricate construction lines of a building, in the broad expanse of the out-of-doors, or in objects within the confines of a studio. Most of the books will be found to refer particularly to architectural drawing in which all the laws and principles of linear construction are directly applicable and most needed.*

The present work has to deal only with the simpler laws of perspective, that known as aerial and color perspective being also important, especially in the drawing of outdoor scenes.

In all the numerous treatises on perspective, illustrations have been found to be indispensable. In fact, they sometimes tell their own story without referring to the text. Figure 8 is therefore intended to convey to the reader the fundamental principles of two-point perspective. Other illustrations will be found in connection with matter relating to block diagrams.

In linear perspective the horizon, whether in view or imaginary, would be a straight horizontal line or trace always level

* Among the books recommended may be mentioned *Perspective,* by A. B. Clark; *Modern Perspective,* by William R. Ware; *Perspective, an Elementary Text Book,* by Ben J. Lubischez; and one of Cassell's technical manuals entitled *The Elements of Practical Perspective.* There are many others.

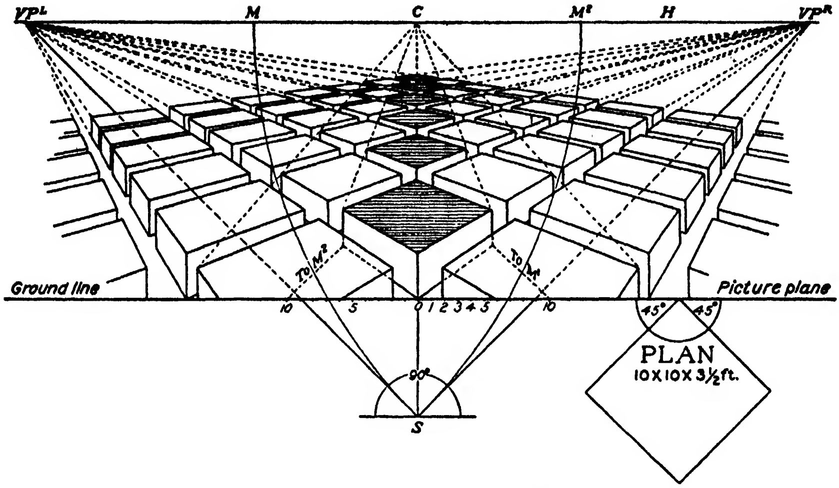


FIG. 8.—Diagram showing the fundamental principles of two-point or oblique perspective and method of establishing the points of distance.

with the eye, whether one is on low ground or on an elevation. Looking straight ahead, the imaginary line of sight would be a vertical line through the center of the picture, ending at the horizon line. This point is called the "eye point" or "center of vision," to which all parallel lines running in that direction, or at right angles to the picture plane, would converge.

In the construction of a perspective layout of a scene, there would be also two points on either side of the center, limiting vision laterally, called vanishing points, in which all parallel lines, if any, running in either direction would also converge and vanish. When buildings or other objects showing linear construction are shown in a picture the foreshortening of the parts which vanish into the distance is shown by the use of what are called measuring points. The location and use of these points in connection with the scale of the drawing is best shown in Figures 17 and 18. Without further description it is believed the figures and text in §46, below, will explain the general principles of linear perspective with sufficient clearness for its use in landscape drawing, as well as in drawing specimens and block diagrams.

Perspective is generally thought of as referring to outside

views, buildings and other works in which construction lines and angles are present. It is, however, also apparent in any object large or small, as, for example, a book or specimen. The same laws apply to both. Everything one sees is in perspective projection, whether it is near at hand or viewed at a distance. All parallel lines, if continued, would converge at one point, and that point would represent the horizon or a point either above or below it. It should be understood that the scale of a perspective drawing is on the picture plane, which might be compared with the ground glass in a camera, and is usually taken from the ground line of that plane.

Aerial perspective.—Unlike architectural and other kinds of drawing, the drawing of a landscape in which there are no works of man calls for only the simpler rules of perspective—that known as aerial perspective, entering more into the expression of distance by the gradual softening of color, tone, and detail, together with the natural diminution of each object.

Brush or pencil outdoor sketching.—A method of starting a drawing to be made in the field having already been described (p. 65, above), the final working up of the drawing should proceed from that point. Having already shown the composition of the picture which should give the proper relative location of each part with some detail and shading, the brush or pencil work should generally begin at the top. If the sky is shown in the view, study the profile or sky line. It will be found that there is really no line there; the picture simply stops against the sky, and its profile should show the character of what is below it. Whether it is composed of trees, foliage, scrub timber, or brush, if not too distant the profile or outline should reflect that character. The fact is there are no separating lines or outlines in nature and none should be shown in a completely shaded drawing.

In filling in areas or masses the general effect of the foliage, grass, or whatever the mass may be composed of should be copied as one sees it. Anything in a landscape beyond a reasonable distance from the eye can be shown only in effect, not in detail; but the effect should nevertheless show individual character.

In a scene showing hills the lines or tints used in shading should tend, sometimes almost imperceptibly, to follow the direction of slope and at the same time give proper emphasis to other details. In drawing a rock or any other object, the same rule of direction of slope is also important and should be followed. The principal endeavor should be to give individual character to each thing portrayed. In the immediate foreground some approach to detail can be indicated; but even so, it should be more impressional than realistic.

If pencils are used in making such a sketch, only a B and an F will be required, the B grade being generally the more suitable. Copying good illustrations of this character will aid in developing a technique, for in drawing trees, especially, and in fact every part of a landscape, it is necessary to hit upon a method or technique most suited to the hand of the individual. A personal technique is just as pronounced in pencil-and-brush drawings as it is in other kinds of artistic work because of the varying direction of strokes produced by the individual handling of pencil and brush.

If the drawing is to be made in washes, lampblack or sepia will give good effects. Brushes should be of red sable, in varying sizes up to about No. 6 or No. 8 according to the size of the picture to be made and the character of detail to be shown.

Pen drawing of outdoor scenes.—Pen drawings are not made directly in the field, for they require greater freedom of action than can be obtained while sketching in the open. They are made from any kind of "copy," whether a crude field sketch done in pencil, in charcoal, or in colors, or from photographs. If a photograph is used, a pen drawing is often made over it and the photograph bleached; but if it is to be simply copied, sufficient detail and character will be shown to guide the pen artist in his drawing. If a pencil sketch is furnished as a basis it should, where possible, be amplified with notes to aid in the interpretation of obscure or imperfect details.

To make a pen drawing for use as an illustration, a technique quite different from that called for in pencil or brush drawings is used, for the reason that each pen line or dot and their spac-

ing must be made so that the drawing will be effective in reproduction. Every line must be of a strength necessary to photograph and etch well. Lines used in shading should not be spaced too far apart; if they are, you see the lines and not the shading—a very bad effect in pen drawing. Yet they must not be too close together. It should be kept in mind that the engraving of a line drawing is more likely than otherwise to show the lines thicker than in the drawing, while the spacing will be reduced in width. All erasures must be very carefully and expertly made and a surface must be left that will take ink without blotting or thickening of lines.

It should also be kept in mind that all drawings made with pen and ink should be larger than publication size, twice linear being the usual enlargement. Good examples of pen-and-ink drawings of this kind but confined to geologic and topographic scenery can be found in the United States Geological Survey Monograph XXXIV, in the *Seventh Annual Report,* especially Plates XXVIII and XXXVIII, and in the *Ninth Annual Report,* Plates XLIII and XLIV.

§25. Classification of Finished Illustrations

When the drawings, photographs, and other illustrations have been assembled for a paper, book, or report, they should be grouped into kinds or classes in order that those in each class may be similarly reproduced and their sizes determined. This procedure insures a more satisfying effect in the printed illustrations as a whole; besides, it can be made to effect economy in reproduction.

Since it is always sound practice to prepare all similar illustrations for one publication in the same general style, their classification should be simple. For example, the pen drawings will form one group, and the photographs will form another; and each of these may be further separated according to the reduction marked on each.

Reductions are generally indicated in fractions, as "½ off," "¼ off," or "Reduce ½," "Reduce ¼," and these reduction marks will aid in the grouping.

When finished illustrations have been classified in this way the engraver will be able to photograph them in groups instead of each one separately, and this contributes to economy in reproduction.

§26. Making Up Plates and Grouping Figures

As drawings are prepared separately and at different times they are often of different sizes and shapes. Since photographs also vary in size it is customary, when a plate is to be made up, to group two or more of these illustrations into one plate; this not only is economical but often permits close comparison of similar subjects. Thus when a drawing or photograph is too small for a full-page plate, it may be grouped with others, even if unrelated to them. While it is usually important to place related figures near each other when possible, a proper balance for the plate as a whole should always be preserved. The best effect is obtained by placing the larger and darker figures in the lower part of the plate, and the smaller and lighter ones above. A very important rule, however, is that the square effect of the plate be always maintained and the open spaces between figures be equalized. A temporary penciled rectangle should be drawn on the mounting card and the figures assembled within the confines of the rectangle. If the plate will consist of one large figure and several others, the smaller figure should be placed above and the larger ones below, or the larger one may be given a place just below the center. Plates made up in this way are more effective without permanent border lines.

Arranging figures on a plate is, withal, a matter of taste and often requires ingenuity in fitting the various parts and in producing the balanced effect already mentioned.

In numbering separate figures on plates two systems are used. The common practice is to use consecutive numbers from 1 to the final figure on each plate. In making references, the plate numbers and the figure numbers are both given; and in case both text figures and plate figures are used, care must be taken to make the reference exact.

The second system, which has found some favor, is to number consecutively all the figures throughout the book. In making references to the figures the plate numbers may be here omitted.

The number designating a figure should properly be placed immediately below it, and a series of such numbers should begin with 1 in the upper left corner and continue consecutively across and down through the plate. This arrangement is not always possible, however, on account of variations in the sizes of figures, which makes consecutive numbering sometimes impossible. Plate XVII shows reference numbers and letters of approved style.

In mounting small drawings or photographs into plates, white or light gray (preferably white) cardboard or matboard should be used, and the figures that are to make up a plate should be arranged as already stated but not securely pasted until the grouping is satisfactory. The separate cards or figures should never be pasted on solidly. By simply adding a spot of mucilage at each of the four corners and one between each corner they will adhere satisfactorily under pressure, and they can be removed more readily if necessary. In trimming each drawing or photograph it is always well to leave room at its lower edge for the number, or, if it is to be a square-trimmed cut, to leave a clear space entirely around the figure. Small drawings or photographs, such, for example, as entomologists and paleontologists use, when pasted on cardboard faced with tough paper, are difficult and sometimes impossible to remove without injury if their positions have to be changed. They can be removed without difficulty by cutting around the edges of the cards and lifting the cardboard facing with the picture (see §10).

Care should be taken that each plate be made up in a size to fit the volume in which it is to be used and that each figure should be properly oriented, that is, arranged so that all vertical lines, or the vertical axis of each specimen, are parallel with the sides of the plate. When the figures are being mounted, care should be taken that the mucilage or paste does not exude under pressure and cover any part of a drawing or photograph.

The same attention is necessary in pasting on numbers. Inattention to these details may produce results that will affect the reproduction of the plates.

Ordinary mucilage is often used for mounting drawings and photographs, but photo paste gives good results and is cleaner. Dry-mounting tissue is well adapted to mounting single illustrations but not groups of figures. White rubber cement is sometimes used, but it is not suitable for mounting small illustrations and not safe for letters and numbers; it can be used satisfactorily for mounting temporary plates and for mounting photographs in albums and on large cards for study or exhibition, but it has not proved to be a permanent and satisfactory adhesive for illustrations. Its special merit is that it does not cause either the photograph or the mounting sheet to warp. It is applied by spreading it evenly over the back of the photograph with a brush or the fingers. The superfluous rubber can easily be removed from the hands and from the cards or sheets when it is dry. Anything mounted with liquid rubber can be easily removed.

If a plate is to be made up of a number of figures that require different reductions (see §5), instead of mounting or pasting the separate figures on one card in the manner already indicated, a rectangle of the size of the printed plate can be drawn on the mount and the several figures that require different reductions sketched in, in their reduced sizes and positions. In making these rough sketches proportional dividers will be found useful in indicating their two dimensions accurately and quickly. The sketching can then be done freehand with sufficient clearness to guide the engraver. These "dummy" plates or layouts should be numbered as plates and bear the usual script headings and titles. The photographs or drawings represented by the sketches are then numbered to identify them with the sketches on the dummy plate, and those that pertain to each plate should be inclosed in an envelope attached to the dummy plate. A plate made up in this manner will meet every requirement of the photoengraver.

In grouping drawings designed for use as text figures (or

cuts) the same method applies in a general way as to plates, except that for reasons of economy their spacing should be just close enough to avoid confusion and the groups should not extend beyond the type measure when reduced. Their best effect is obtained by having the groups appear slightly narrower than the text. It should be remembered that a text figure may cover the entire text page, or any part of it, but it cannot extend beyond the limits of the type matter in either direction.

The separate parts of a text figure bear letters instead of the numbers used in plates (see §3).

§27. Preliminary Preparation of Maps

Author's preparation.—Preliminary maps naturally differ greatly in character and in degree of clearness. Some are carefully prepared, while others are rough and even defective in detail. Any draftsman who may be employed to make finished drawings from such copy will need definite instructions; hence the information the map is to carry should be completely assembled and should show no uncertainty not fully explained in marginal notes.

The author's base map may be an original field sheet, or it may have been compiled from other sources. As a rule a collection of maps of different scales and standards to be worked into a new base map by a more expert draftsman is unsatisfactory unless the cost of repreparation is not a consideration and the map is to be of outstanding importance.

Source of data.—The source from which every map is compiled should be indicated on the map, whether it is to be used as an illustration or as a record of field work. Such a record is always useful in showing the reliability of the map and in assigning full credit to those who are responsible for it. When this requirement is observed, all co-operative agreements and organizations, if any, can be properly mentioned. An author's original map should be complete in itself when possible. All elaboration or technical finish of border lines, marginal lettering, or other such features can be left to the draftsman, or to the engraver if the latter is instructed to furnish such finishing.

It is always well to remember that if the three fundamental features of a topographic map—the culture, the drainage, and the relief—are to be engraved or photolithographed and printed each in a separate color, *the best results are obtained by drawing each feature in a separate color on one sheet.* The culture may best be drawn in black waterproof ink, the drainage in Prussian blue, and the relief in burnt sienna; but care should be taken that the colors used will photograph well. To insure a good photograph it is usually necessary to add a little black to the blue and the brown. The lithographer will make three negatives and will opaque or paint out all but one of the three features on each negative. The cost of doing this is somewhat greater than in reproducing three separate sheets, but the result is more accurate register. If the drawings are made on separate sheets, they are liable to change slightly in size through atmospheric influence before they are reproduced.

Base maps clear of data.—Important base maps should be kept clear of technical symbols or data of any kind. After preparation each map can be photographed (sometimes to publication size) and the information it is to bear may be added to the photographic copy. If this rule is followed, considerable expense in reproduction will be saved and the base may be brought into use again for other purposes. (See also "Hill shading," under §34, p. 95.)

§28. Material Available for Base Maps

All the maps published by the United States Geological Survey* and other federal bureaus should be consulted when a new base map of any part of the national domain is to be compiled. The following list includes most of the maps available for that purpose:

1. *The Survey's regular topographic atlas sheets,* published on three scales—15-minute sheets, scale, 1: 62,500; 30-minute sheets, scale, 1: 125,000; 60-minute sheets, scale, 1: 250,000 (approximately 1 mile, 2 miles, and 4 miles to 1 inch, respectively). It also issues certain "special" maps, some of which

* See "Topographic Maps and Folios and Geologic Folios" published by the United States Geological Survey, latest editions.

are published on other scales. All these maps can be used as bases for detailed geologic maps, for compiling maps on small scales, and for revising other maps.

2. *The United States part of the international map of the world,* published on the scale of 1: 1,000,000 (approximately 16 miles to 1 inch). Each sheet of this map represents an area measuring 6° of longitude and 4° of latitude. The published sheets may be used as bases for general maps. The sheets are drawn on the scale of 1: 500,000, and photolithographs on this scale are available for use as bases for geologic or other maps. The adaptability of the 1: 1,000,000 scale map for use as a base for general maps is shown in maps of the southern peninsula of Michigan and of Indiana in *U.S.G.S. Monograph 53* (Plates IV and VII), the map of Florida in *Bulletin 60* (Plate I), and the map of Vermont in *Water Supply Paper 424* (Plate I).

3. *The United States Geological Survey's two-sheet wall map of the United States,* 49 × 76 inches, scale 1: 2,500,000 (approximately 40 miles to 1 inch). Parts of this map can be used as bases for general maps and for index and other small maps. This map is published both with and without contours.

4. *United States Land Office maps and township plats* are published on a scale of 12 miles to 1 inch; they are also photolithographed on one-half that scale, or 24 miles to 1 inch. The township plats are printed on a scale of one-half mile to 1 inch. The maps are especially useful in compiling maps in which land lines (townships and sections) are essential, and the township plats afford valuable detail and are useful in field work and in revising other maps. Township and section lines should appear on all land-classification maps. On maps on a scale less than 1: 250,000, only the townships should be shown; on maps on scales greater than 1: 250,000, the sections are sometimes shown, unless their representation will impair the legibility of the map, in which case only the townships should be shown. (See Figure 9.)

5. *Post-route maps,* covering single states or groups of adjacent states, published on sheets of different sizes and on scales determined mainly by the size of the states. The map

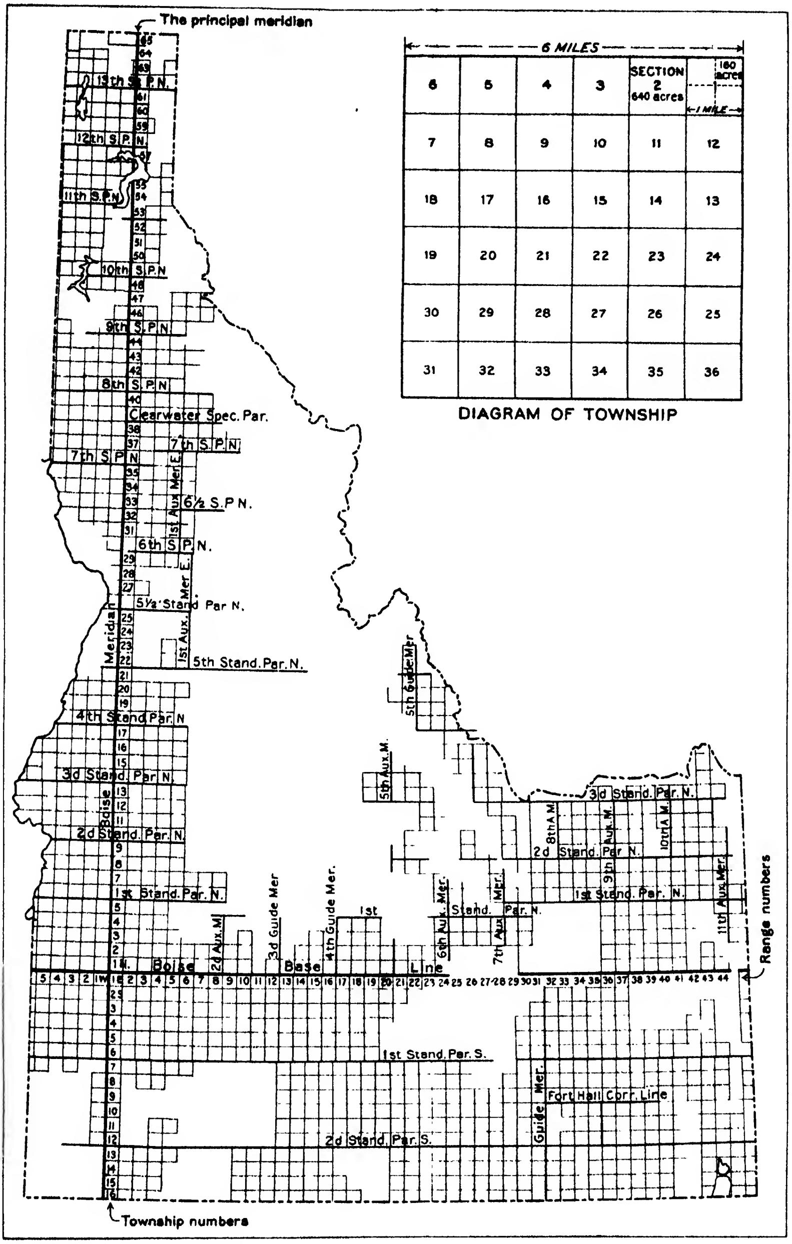


Fig. 9.—Diagram showing principal, guide, and auxiliary meridians, standard and special parallels and correction lines, and system of numbering townships, ranges, and sections.

of Texas is published on a scale of 12 miles to 1 inch, that of Virginia on a scale of 7 miles to 1 inch, and that of West Virginia on a scale of 6 miles to 1 inch. Both the United States Land Office and the Post-route maps are useful for reference in compiling maps on smaller scales. Post-route maps are especially useful for comparing and verifying the location of cities, towns, and railroads.

6. *United States Coast and Geodetic Survey charts,* published on scales that depend upon the area represented and the amount of detail to be shown. These maps should always be used in compiling and correcting coast lines and contiguous islands.

7. *Maps and charts published by the Corps of Engineers of the Army, The Mississippi River Commission, the Surveys of the Great Lakes, and the Boundary Surveys.* These maps are especially useful when the scale of the map to be compiled will permit of considerable detail.

8. *The United States Geological Survey's three small base maps of the United States*—(*a*) a map 18 × 28 inches, scale 110 miles to 1 inch, which is published both with and without contours, or with hypsographic shading; (*b*) a map 11 × 16 inches, scale 190 miles to 1 inch; (*c*) a map 7½ × 12 inches, scale 260 miles to 1 inch, designed for use as a two-page illustration in octavo publications.

9. *National Geographic Society maps,* published from time to time, contain the latest information covering the areas represented. They are prepared by expert cartographers and are therefore based on correct projection. They will be found useful in compiling other maps of similar areas.

10. *The Century, Rand McNally & Co.'s, Cram's, Stieler's, The Times, Johnston's Royal, and County Atlases.*

11. *State and county maps.*

12. *Railroad surveys,* which are useful in furnishing data for elevations as well as for locations of towns and stations.

13. *The latest National Forest maps and proclamations.* It is rarely necessary that National Forests, bird reservations, and National Monuments be shown on a map, and they should not be shown if they will obscure other important data.

14. *National Park maps,* on scales varying with the size of the area included.

The Geographic Board (formerly called "Board on Geographic Names") was created by executive order September 4, 1890, made up of members from the State Department, Coast and Geodetic Survey, Geological Survey, Engineer Corps, and also other government bodies. The Board passes on all unsettled questions concerning the spelling of geographic names and determines changes such as the dropping of unnecessary letters or symbols and the closing of compounds. Its decisions are accepted as standard authority by all departments of the government. Issued at intervals of several years, its publications contain all decisions made by the Board from its organization to date. They can be obtained from the Superintendent of Documents, Government Printing Office.

§29. Generalization of Maps

As has been said, "every map, whatever its scale, is a reduction from nature and consequently must be more or less generalized."* The degree of generalization of data to be shown on a base map usually involves a corresponding degree of generalization in its base. Absolutely true generalization should mean the same degree of omission of detail for each kind of feature. Yet if a base map on a scale of 1 inch to 1 mile, prepared with the usual detail, were placed before a camera and reduced to a scale of 16 miles to 1 inch, the lines representing the small tributaries of streams and the smaller water bodies, as well as many other features, would probably be so greatly reduced as to be negligible. If from this reduced photograph a new map were prepared, from which all features not plainly discernible were omitted, the new map would represent what might be called true generalization. Although this degree of generalization is not always practicable, unessential details should be systematically omitted.

The amount of detail which a base map should show is limited by its scale, by the character of the country it repre-

* Henry Gannett, *A Manual of Topographic Methods, U.S. Geological Survey Monograph 22,* 1893, p. 107.

sents, and by the kind of data to be shown. Two co-ordinate features of a topographic map should be shown with equal detail. Detail in culture may call for detail in drainage, though relief may be greatly generalized or entirely omitted; detail in relief may likewise call for detail in drainage, though culture may be more generalized.

§30. Final Preparation of Maps

Though base maps furnished by authors are prepared in many different ways and with different degrees of refinement of drawing, the work of redrawing them for reproduction involves well-established and generally uniform principles.

Projection.—All maps except those of very extensive areas should be based on a map projection which will show with a minimum of distortion the effect of curvature of the earth. The polyconic projection is used for most government maps and should be consistently used in miscellaneous mapping. In this projection the central meridian is a straight vertical line, and each parallel of latitude is developed independently of the others. The mathematical elements of map projection are given in tables published by the United States Geological Survey* and the Coast and Geodetic Survey.† Figure 10, however, illustrates the mechanical or constructional features of the polyconic projection and if used in connection with the tables reproduced on pages 151–61 will probably be a sufficient guide for projecting a map on any desired scale.

To project a map first select a convenient measuring scale for setting off the dimensions given in the tables referred to; if no scale is at hand, one may be constructed. Measuring scales, however, are made by firms manufacturing drawing instruments, bearing divisions for miles and kilometers and finer subdivisions of 5 to 100 parts. They include the ratios of 1: 31,250, 1: 31,680, 1:48,000; 1: 62,500, 1: 63,360, 1: 125,000,

* S. S. Gannett, *Geographic Tables and Formulas,* 4th ed., *U.S. Geological Survey Bulletin 650,* 1916. See also C. H. Birdseye, *Formulas and Tables for the Construction of Polyconic Projections, U.S. Geological Survey Bulletin 809,* 1929.

† *Methods and Results: Tables for the Projection of Maps and Polyconic Development,* Appendix No. 6, Report for 1884; *Tables for a Polyconic Projection of Maps, based upon Clarke's Reference Spheroid of 1886,* 3d ed., 1910.

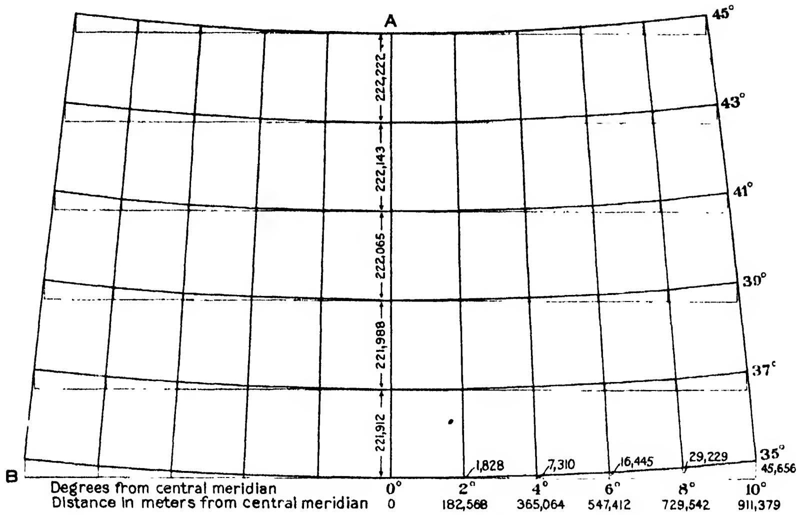


FIG. 10.—Diagram illustrating method of projecting a map

1:250,000, 1:500,000; 1:1,000,000, and others. On a map drawn on the scale of 1 to 63,360, for example, 1 inch would represent 1 mile; on a map drawn on the scale of 1 to 1,000,000, 1 millimeter would represent 1 kilometer, and so on. It will be seen that the use of a scale that shows, in ratios, such as those just given, the actual distance on the ground as compared with the unit representing the same distance on the map will reduce the possibility of error.

The accompanying diagram (Figure 10) illustrates the method of projecting a map: First draw a straight vertical line (*A*) through the middle of the sheet to represent the central meridian of the map and a line (*B*) at the lower end of this line exactly at right angles to it to represent the bottom of the map. Then set off on the line showing the central meridian the distances between parallels given in Table I.* It should be noted that the figures in this table give the distance, in meters and statute miles, of 1° on a meridian measured 30′ each way from a point where the meridian is intersected by a parallel. The exact distances between parallels as measured on the ground may be

* See the Appendix to this book, p. 151. Tables I to XI, inclusive, of the Appendix are from S. S. Gannett, *Geographic Tables and Formulas, U.S. Geological Survey, Bulletin 650.*

computed from Table I by adding the sum of the figures given for any two latitudes 1° apart and dividing by 2.

The distance between parallels that are 2° apart, as shown in the diagram, may be computed from Table I, as follows:

1° of latitude on 37th parallel = 110,975.1 ÷ 2 =	55,487.5
1° of latitude on 36th parallel =	110,956.2
1° of latitude on 35th parallel = 110,937.6 ÷ 2 =	55,486.8
True distance from 35° to 37° latitude....	221,930.5

The distances given in the diagram were obtained by adding the figures given in the Coast and Geodetic Survey tables, which yield the same results.

Through the points thus obtained on the central meridian, draw lines at right angles to the vertical line. Along these horizontal lines lay off for each latitude the dimensions in the column headed *X*, Tables III–XI (pp. 153–61), as required for each individual map—in the diagram every alternate degree. Draw vertical lines at these points and set off the distance *Y* in the same table in a similar manner, and the points so found will be the points of intersection of the respective meridians and parallels. Figures are given in the diagram for the thirty-fifth parallel only.

The theory and mathematical development of the projection adopted for the international map of the world is also explained in *United States Geological Survey Bulletin 809*, by C. H. Birdseye, in which tables for its construction are given along with the data in meters on the natural scale as well as in inches on the scale of 1: 1,000,000.

In this modified polyconic projection all the meridians are represented on a map as straight lines, whereas in the true polyconic method each meridian (except the central one) is a curve, concave toward the central meridian. Bulletin 809 also explains the mathematical development of true polyconic projection with instructions for its construction, together with tables giving exact measurements on paper, in inches.

The reader is also referred to *Cartography*, by Charles H. Deetz, *Special Publication No. 205*, Coast and Geodetic Survey,

1936, for sale by the Superintendent of Documents, Washington, D.C. This book will be found not only useful in the construction of maps but also an interesting exposition of the general subject of map making.

Orientation.—When a map bears no arrow indicating north it is supposed to be oriented with its top to the north, and its title should read from west to east. If, however, the area mapped has a general trend in one direction, as northwest to southeast, and its squaring up by a north-south line would leave too much blank paper, this general rule is not followed. The border lines on such a map should conform to the general trend of the area mapped, an arrow should show north, and the title and scale should be placed horizontally; but the projection numbers and town names should follow the direction of the parallels of latitude. (Maps oriented in this way are shown in Plates X and XII, *United States Geological Survey Bulletin 628,* and Plates VI, XV, and XVI of the Survey's *Monograph 52.*)

Component parts of a base map.—The first requirement in drawing a base map is that the draftsman know how each part of the map should be represented. The conventional symbols for the various features which compose a base map are well established and should invariably be used; for example, a line composed of alternate long and short dashes represents a county boundary, and a line across which short lines are drawn at regular intervals represents a railroad. The correct forms of all of the conventional symbols referred to are shown in Plate XIV, but the size and weight of each line or symbol must depend on the size and character of the map. If it is found that two or more symbols have been widely used to represent the same feature, the draftsman should select the one that is best suited to the map in hand.

Conventional setup for finished maps.—Probably the most complete, esthetic, and mechanically perfect large series of maps yet published in this country are those issued by the United States Geological Survey and other government bureaus. They include the topographic atlas sheets, the geologic

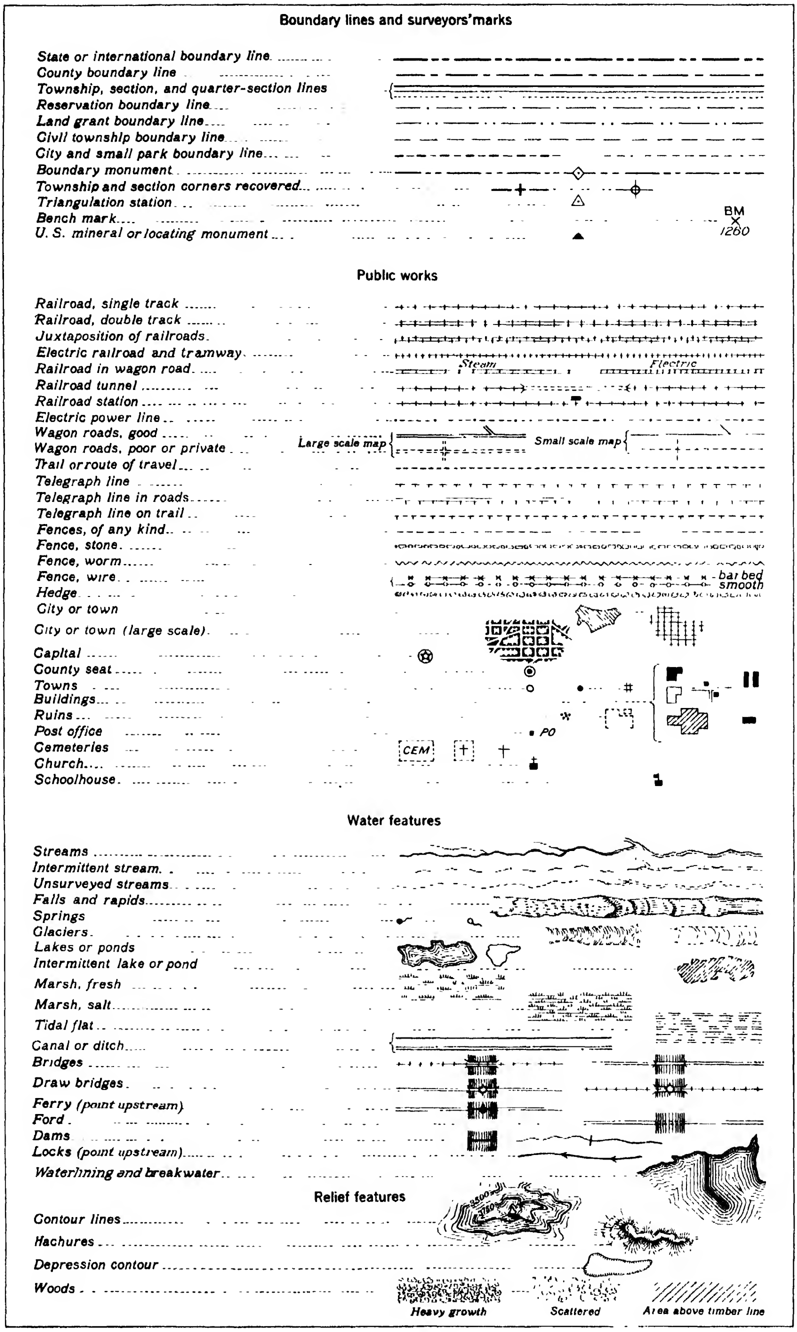
folios, and numerous Coast and Geodetic Survey charts. It would also be entirely proper to include many miscellaneous maps which accompany reports of other government bureaus and those of the National Geographic Society, all of which were originally prepared by expert cartographers. In the preparation of these maps a standard conventionality has been developed and details of their construction are well worthy of emulation by other publishers.

Plate XV in this book was designed to show the generally accepted styles evolved in the representation of a border, title, legend and position of explanatory boxes, credit notes, scales, kinds and relative sizes of letters, spacing, magnetic declination, position of scales, and other features worth following in constructing similar maps. In the simpler kinds of maps the standard conventions are not strictly followed.

Borders.—A map border is used or omitted according to the kind of map prepared. Small diagrammatic maps and maps on which no parallels and meridians appear do not need finished borders. On a map that is not completely colored and on all very large maps borders seem to be necessary. If borders are used, however, the space between the neat line and the outer line of the border should be sufficient only to provide proper space for the numbers showing latitude and longitude or township and range. A simple rule* for determining the width of this space is as follows: Divide the sum of the dimensions of the map by 2 and find the square root of the quotient; this will be the width of the border in sixteenths of an inch. Example: Map is 20×30 inches; $\frac{20+30}{2} = 25$; square root of $25 = 5$; width of border $= 5/16$ inch. On a map with border lines the numbers showing latitude and longitude should be in Arabic numerals and those showing township and range in Gothic. On a map that has no added border lines the numbers should be in Hair-Line Gothic. The symbols for degree, minute, and second should not be crowded.

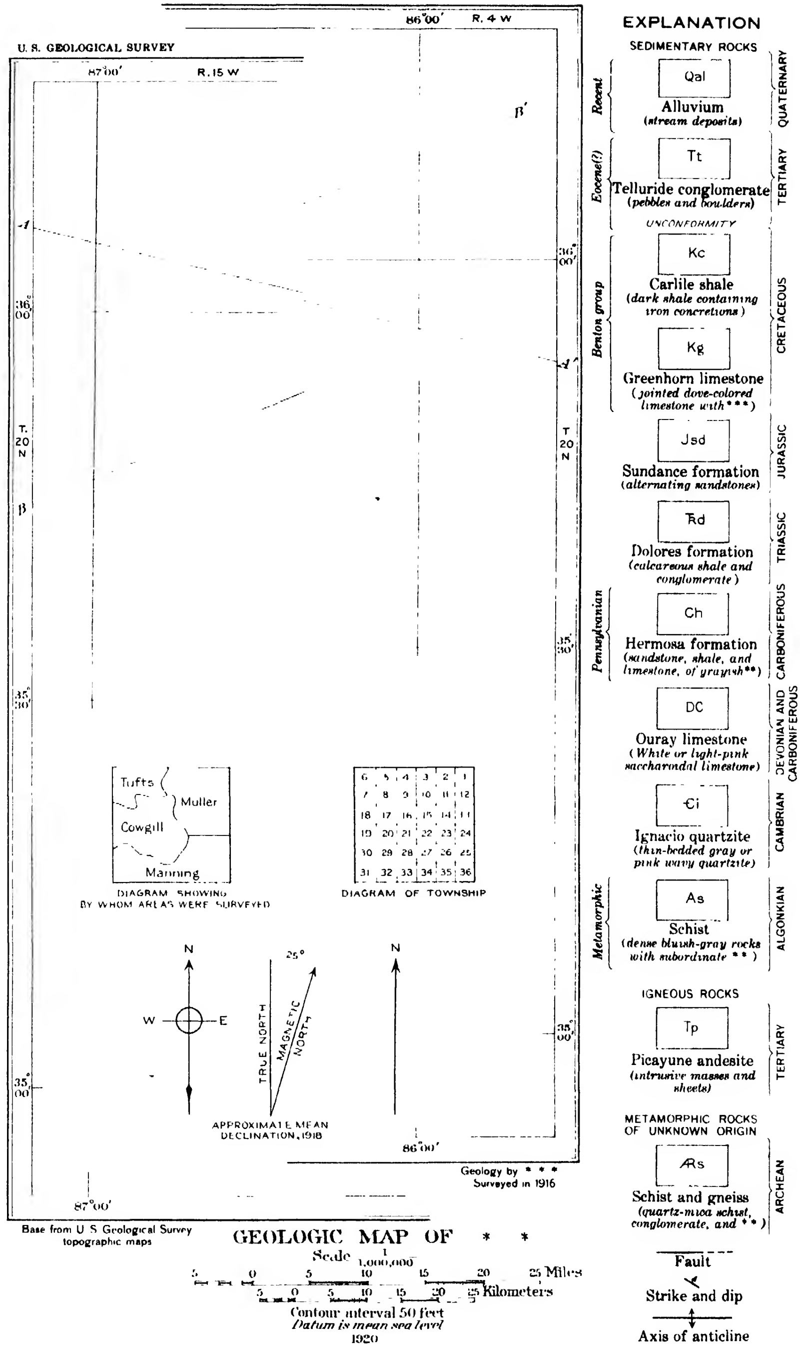
* Devised by Martin Solem.

PLATE XIV



Component parts of a base map

PLATE XV



Details of the makeup of a finished map

Titles.—A map title should properly be in Roman letters and if placed at the lower margin should generally be arranged in two lines, unless it is short. If it forms two or more lines, the lines should be well balanced. The first line should describe the position of the area; the second line should state the purpose of the map, as

MAP OF BUTTE AND VICINITY, MONTANA
Showing Location of Mines and Prospects

A title placed inside the border of a map should be arranged in a series of lines, generally beginning with "Map of," or "Climatic map of," and the line showing the dominant part of the title should be emphasized by larger lettering, thus:

MAP OF
THE VICINITY OF BUTTE
MONTANA
Showing Location of Mines and Prospects

The name of the author or compiler of a map or of the person supplying its scientific data is placed either beneath the title or in the lower right-hand corner, and the names of the topographers or the source of the base is stated in the opposite corner, as shown in Plate XV.

Titles are reproduced directly only on lithographs, three-color or multicolor prints, photogelatin plates, and other illustrations that are printed by the "engravers," not by the publishers. Titles that go with illustrations printed by relief processes such as zinc etching, wax engraving, and half-tone, are added by the printer from the manuscript.

Explanation of data.—Under the heading "Explanation" (sometimes called "Legend" or "Key") is placed all matter needed to describe fully the details of an illustration, whether map, diagram, or section, so that if the illustration becomes detached it would be a complete self-explanatory unit. If the explanation is small, a convenient place for it may sometimes be found within the border. If no space is available there it may be placed either vertically along the lower right-hand margin or

horizontally under the title. In a geologic map or a map showing precipitation, for example, the explanation should preferably be arranged vertically. This explanation should be carefully worked out in pencil and approved before it is drawn in ink, in order to save time in making corrections.

If type impressions are used, the explanation should be in Roman letters for the titles under the boxes and italic of smaller size for the subtitles or descriptive detail, which should be inclosed in parentheses. The explanation should not be crowded, and if corrections are necessary they should be so made that each line of the matter in which they appear will be properly spaced. Where hand lettering is used for this explanatory matter, light-faced Gothic, either upright or slanting, is appropriate; but the arrangement shown in Plate XV should be followed.

The explanation or legend for a map that is to be engraved or to be reproduced by lithography need only be sketched in to show general style and arrangement. The engraver or the lithographer will supply such matter in proper form according to instructions. For direct reproduction, however, as by photolithography or zinc etching, the lettering must either be carefully drawn with pen or printed from type on slips and pasted on the drawing.

Standard scales.—The standard scales of maps used in most government publications are either fractions or multiples of 1: 1,000,000 (see §28), except for a map that is reduced expressly to fit one or two pages of a report or that is reduced horizontally or vertically to fit the text, such as a small diagrammatic or index map. It should be remembered that a map which may be serviceable for use in compiling a new map can be reduced or enlarged to the scale of the new drawing by photography, by pantograph, photostat, or other means (see §41).

Graphic scales.—A bar scale for miles or feet should be given on every map, and if the map is of international interest the metric scale should appear just beneath the scale of miles or feet. The accepted designs for these scales are shown in Figure 11. The scale should be accompanied by any necessary

statement pertaining to the base map, such as "Contour interval 20 feet," "Datum is mean sea level." The fractional scale, $\frac{1}{250{,}000}$, for example, is generally stated on all except the simpler kinds of maps, and the date of publication should also appear just below the scale or scales. The single-line bar scale is used only on small maps. The length of the bar scale must depend on the size of the map and the space available, and its smaller divisions should be in fifths or tenths. Those shown in Figure 11 were made over blueprints from scales used on well-known maps.

§31. To Make a Scale for Map of Unknown Scale

To make a bar scale for a map of unknown scale that shows only a single meridian and parallel, or for a map on which no meridians or parallels are shown, first ascertain the distance between two points shown on the map by reference to other authentic maps. If, for example, the distance between two such points is 16.315 miles, draw a horizontal line (*a* in Figure 12) representing this distance on the map; and at its end, at right angles to it, draw another line (*b*) actually measuring 16.315 units of any convenient denomination. Draw a straight line (*c*) diagonally between the ends of lines *a* and *b*. Then set off on line *b* any convenient number of the units selected, say 5 or 10, and project, from the points thus set off, lines exactly parallel with line *c* to line *a*. The distance and the number of the units thus marked on line *a* will indicate the number of miles covered by that distance on the map, as shown in Figure 12.

For tables of distances between meridians and parallels see Tables I and II of the Appendix to this book (pp. 151–52).

§32. Symbols Representing Miscellaneous Data Used on Maps

General features.—Symbols showing data of any kind should be drawn with care and be accurately located. The size of a symbol will depend upon its relative importance. On a map that shows numerous mines, for instance, the crossed hammers

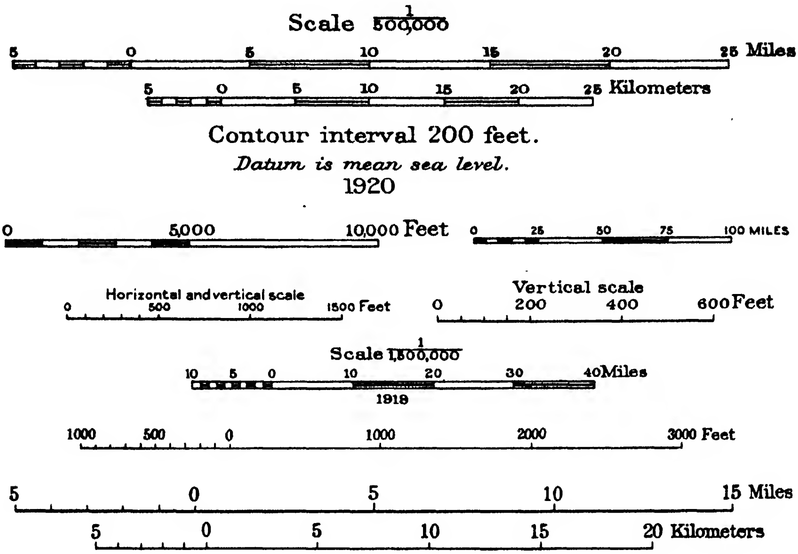


FIG. 11.—Standard designs for bar scales

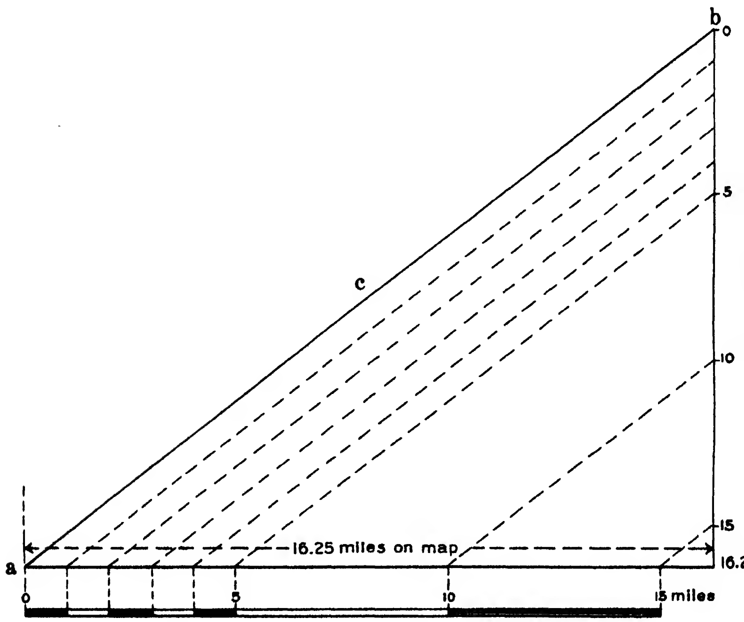
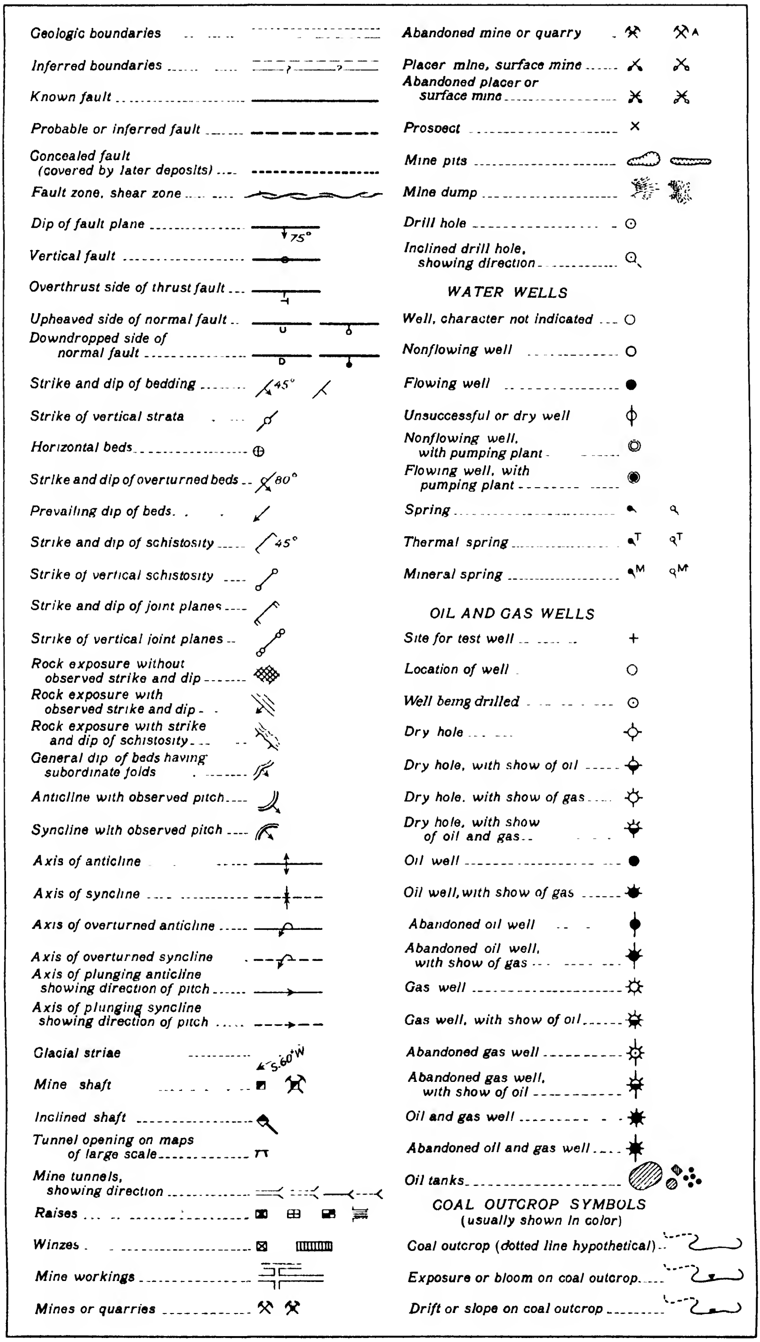


FIG. 12.—Diagram showing method of making a bar scale for a map of unknown scale

PLATE XVI



Geologic and economic symbols used on maps and plans

should be conspicuous but not too large. If it is known beforehand how much a map will be reduced, the symbols can be made exactly in proportion to reduction. This may be computed on the basis of about two millimeters for the smallest symbol after reduction. The standard symbols shown in Plate XVI are those used when appropriate.

Careful enumeration indicates that more than two hundred symbols are known to have been used on maps to express twenty-five different kinds of data, a fact indicating a notable lack of uniformity and a need of standardization. It is of course impossible to provide a characteristic symbol for each kind of feature, and therefore the same symbol may sometimes be used on different maps to express different things. The symbols shown in Plate XVI cover all the ordinary requirements of miscellaneous mapping. It is always well to remember that the center of a symbol is intended to mark its location; on small-scale maps they are not always plotted with sufficient accuracy, and unless the utmost care is taken in plotting them they are likely to be several miles out of place.

The symbol showing dip and strike should be plotted by means of a protractor, so that the strike will be shown graphically without a number and a degree mark and not need replotting by a draftsman or engraver. The dip, however, should be indicated by a number and a degree mark.

Geologic letter symbols.—The standard letter symbols used on geologic maps to indicate the ages and names of the formations represented consist of two or more letters—an initial capital letter for the name of the system and one or more lower-case letters for the name of the formation or of the material—as Qlt (Quaternary—*lower terrace deposits*); Tt (Tertiary—*Telluride conglomerate*); Kc (Cretaceous—*Carlile shale*); Jsd (Jurassic—*Sundance formation*); ₮d (Triassic—*Dolores formation*); Cpv (Carboniferous—*Pottsville sandstone*); Do (Devonian—*Ouray limestone*); Sm (Silurian—*Medino sandstone*); Otl (Ordovician—*Trenton limestone*); Ꞓ Ok (Cambrian-Ordovician—*Knoxville dolomite*); As (Algonkian—*schist*); AR (Archean—*schist and gneiss*). (See §44 for standard colors.)

A letter symbol, such as has just been described, should be put in the proper place in the explanation or legend of a geologic map and repeated at one or more places on the map within the areas to which it refers. It is always safer to mark each area that is indicated by a color with a symbol in order to make its identification sure, since light colors, especially, are likely to fade, and mixed colors, as stated in §43, cannot be discriminated with certainty.

Oil and gas symbols.—A complete set of symbols for maps showing oil and gas data also is shown on Plate XVI. They conform largely to commercial use and embrace its best features as well as the most logical features of previous usage. These symbols are founded on a building-up system, so that the history and the results of drilling at any location can be recorded by slight additions to a symbol and without erasure. Thus maps may be revised without scratching.

In drawing these symbols the draftsman should make the rays of the gas well distinct, and in adding the vertical bar or line showing that a hole is dry or abandoned should make it long enough to be distinct. It would be preferable to draw this bar obliquely, but an oblique position would coincide with some of the patterns on certain maps, and it should therefore be placed vertically. The vertical line indicates the failure or abandonment of the well, the symbol for which is thus scratched off or canceled by the line drawn through it.

§33. Ground-Water Data

The colors and symbols used on maps relating to ground water represent the features named below, each of which has been shown far from uniformly in many publications already issued.

Area of absorption or outcrop
Depth to water table
Contours of water table
Fluctuation of water table
Depth to water-bearing formation
Structure contours of water-bearing formation
Head of artesian water
Area of artesian flow
Area that discharges ground water
Quality of ground water
Area irrigated with ground water
Non-flowing well
Flowing well
Unsuccessful or dry well
Well with pumping plant
Spring

Colors and tints used.—The lack of uniformity in the colors commonly employed to represent these added features is due to differences in the number of colors used on the maps and differences in the scale. Standard colors for the larger features, such as those for areas of artesian flow, areas of absorption, and curves showing depths to water table or to water-bearing formations, cannot be fixed because of considerations of economy in printing. For example, if light green is the standard color to be used for delineating areas irrigated by ground water and no green is used on other parts of the map, its use would represent an additional or special printing, whereas a fine reticular tint of blue, brown, or purple, if any of these colors is used for other features on the map, might be used also for this feature without additional printing. Therefore the general use of any particular color for a water feature seems to be impracticable; but this fact should not preclude the adoption of a standard range of colors subject to the requirements of economy in plate-making and presswork.

The following colors and symbols can appropriately be used to represent ground-water features. The well-and-spring symbols can be varied by adding letters if it is necessary to express other data than those indicated in the list below:

Area of absorption or outcrop: Flat color used on the map to show the geologic system in which the absorbing formation occurs.

Area showing depths to water table: Shades of purple and gray; if possible the shades showing the areas of least depth should be darkest and the shades should grade from those to lighter shades.

Contours of water table, or contours of water-bearing formations: Gray or purple curves or lines.

Areas of artesian flow: Blue flat tint, or fine ruling in blue.

Depth to water-bearing formations: Gradation of a single color or of two related colors from dark for shallow depths to light for greater depths.

Non-flowing artesian areas (pumped wells): Green flat tint or fine ruling in green.

Depth to water-bearing formations: Shown by gradation of tint if possible from dark for shallow depths to light for greater depths.

Head of artesian water: Blue curves or lines.

Areas that discharge ground water: Blue flat tint, or fine ruling in blue.

Areas irrigated with ground water: Green flat tint, or fine ruling in green.

The following symbols are shown either in blue or in black:

- o Well, character not indicated
- ○ Well, non-flowing
- ● Well, flowing
- ɸ Well, unsuccessful or dry
- ◉ Well, flowing, with pumping plant
- ● Well, flowing, with pumping plant
- ♀♀ Springs
- ♀T Spring, thermal
- ♀M Spring, mineral

The standard color scheme described above should be used if no conditions preclude its use, but if other colors can be used with greater economy and without sacrificing clearness its complete adoption is always waived.

The symbols for wells are the open circle and the solid circle. Only in the secondary or specific well symbols does there appear to be lack of uniformity, the choice being governed either by personal preference or by the requirements for specific distinction.

Each symbol should if possible suggest the thing it represents. For example, a well is circular, and hence the open circle is most used and most appropriate for a non-flowing well. If it is a flowing well, the circle is made solid, denoting that the well is full of water. For an unsuccessful well the most suggestive symbol would be an open circle with a line drawn through it. (It has been suggested that if water features, including wells, are to be printed in blue, unsuccessful wells or dry holes be printed in black.) A larger circle drawn around the symbol for a flowing or non-flowing well will appropriately denote a pumping plant at the well.

The standard symbol for a spring is a blue or black dot or circle with a waved tail to indicate direction of flow, if known. Any of these symbols may be accompanied by a letter indicating the kind of spring. The open circle is used on large-scale maps, whereas the black or blue dot and tail will fit maps of any scale.

§34. Topographic Features

Relief.—Relief on a map is expressed by contours, by hachures, or by shading. The first method does not give a pictorial

expression of relief, though it gives correct shape and exact elevation; the others are more pictorial but they do not give exact elevation.

Contours.—As original contoured maps are always prepared from actual surveys, the draftsman who follows the field work of the topographer can copy the original matter only as presented for redrawing or inking in. If the area mapped is large and the contours are close together, the original may be transferred by tracing with graphite-coated paper or other means. After the contour lines have been transferred they are traced with ink in lines of even thickness, except those that represent certain fixed intervals and are to be numbered; these are made slightly thicker, as in Figure 13. In drawing these lines an ordinary ruling pen or a swivel pen may be used; but considerable practice is required in the use of either before it can be controlled so as to follow precisely the penciled lines. Sometimes the Shepard pen or an ordinary drawing pen is used. The swivel pen, if expertly handled, produces a firm and even line.

Italic numbers are used to indicate the elevation of a contour and should be placed in an opening in the line, never between lines. Where the lines run close together great care should be taken that they do not touch unless the interspaces are so narrow that they must touch and combine. The lines should be firm and even, and if the copy or original map shows that they are uniformly very close together it should be photographically enlarged before the tracing is made in order to give more freedom in drawing; but if the enlarged map is much reduced, care should be taken to make the lines heavier in proportion to the reduction. A reduced photoengraving of a map on which the contour lines are drawn very close together is likely to be unsatisfactory, because, though the spaces between the lines are reduced in width, the lines themselves may show no corresponding reduction in thickness.

The contour lines commonly accentuated on a map are every fourth or fifth—that is, for a 10-foot interval every 50-foot line, for a 20-foot interval every 100-foot line, for a 25-foot interval

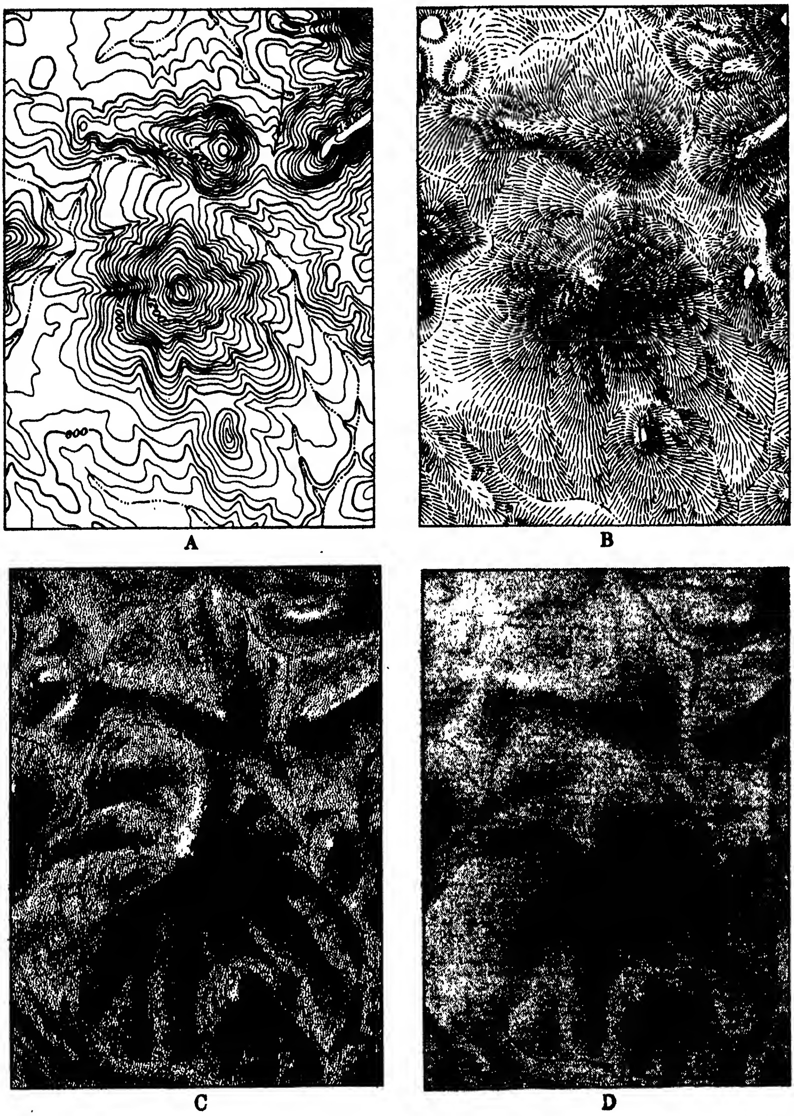


Fig. 13.—Method of expressing relief (*A*) by contour lines, (*B*) by hachures, (*C*) by shading on stipple board, and (*D*) by shading with brush.

every 100-foot line, for a 50-foot interval every 250-foot line, and for a 100-foot interval every 500-foot line.

Hachuring.—Much experience is needed to draw hachures with such freedom of stroke as to look well and at the same time represent topographic character. In a hachured map the light

should seem to come from the west, that is, the darker parts should be on the east side of an elevation and the lighter parts on the west. The highest elevation should be represented by the darkest shade on the right and by a corresponding highlight on the left. The hachuring should begin at the crest of a peak, range, or butte and be worked downward toward the gentler slopes, the lines being drawn farther apart and made thinner until the floor of the valley is reached and the effect of shadow is lost by fewer and lighter lines. On a hachured map that is made from a contoured map somewhat definite differences of elevation may be indicated by the intervals between the strokes, and abrupt changes in slope may be indicated by shorter and heavier lines. The strokes should be disjointed, should trend at right angles to the upper margin of a cliff, and should radiate from a peak. Figure 13 represents satisfactory hachuring.

Hill shading.—It is not difficult to express relief by shading if one is familiar with light and shade and knows the character of the region. The draftsman can best express it by this means after he has studied contoured maps or photographs of the region mapped, if they are available, in order that he may obtain an idea of the character of its topography.

Several methods are used in producing hill shading, each of which depends on the character of surface of the paper on which the drawing is to be made, the size of the map, the amount of detail and refinement of execution desired, and the amount of reduction to be made when the drawing is engraved. For maps on which it is desired to show some detail in the topography, a paper having a grained surface may be used upon which the shading is added with a lithographic or wax crayon. The draftsman must express relief according to the information he has at hand, whether detailed or general, and must employ methods that accord with the purpose of the map and the mode of reproduction decided upon. If a shaded relief map is to be prepared for direct reproduction by photolithography and the shading is to be printed in a separate color, the base map having been completed first, a light photographic print, or blueprint, should be made upon which to add the relief to insure its perfect fitting

with the base; or the relief can be prepared on an oversheet of semitransparent white paper with sufficient "tooth" or grain to cut the shading up into minute dots. The shadowless drafting table (see §41) is especially useful for this purpose. On this oversheet register marks should be placed at the four corners and at several other points, particularly at the intersection of parallels and meridians.

Satisfactory relief shading on small black and white maps can be made on Ross's Hand-Stipple drawing board and other similar papers (see §10). By rubbing a black wax crayon or pencil over the surface of this paper the desired effect is produced in fine dots or stipple, which may be varied in density of shade at the will of the draftsman (see Fig. 13, *D*). Highlights can be produced by scraping away the chalky surface of the paper. The wax crayon already mentioned is the best medium to use on this stipple paper, as on the slightly grained paper referred to in the preceding paragraph, for it is not so easily smeared as that produced by a graphite pencil. The object of using either the rough paper or Ross's Stipple Paper for drawings that are to be reproduced by photoengraving is to produce a shading that is broken up into dots of varying sizes, which is essential in such reproduction.

Relief can also be expressed with a brush in flat washes of either India ink, lampblack, or sepia. Such shading should be made over a blueprint or an impression of some kind from the base map upon which the shading or relief is to be overprinted. If the relief is expressed on the author's original by contours, the general shape of the relief and the drainage lines can be traced and transferred lightly in blue lines to the new map from which to model the shading and at the same time to make the topography fit the streams. Such a drawing is photographed through a screen and reproduced as a separate color plate with which to overprint the map.

The most successful and best method of expressing relief on a map, however, is to draw it over a blueprint (or a very light photoprint) of the base upon which it is to be overprinted in a separate color.

§35. Hydrography

Streams.—Streams on a map should not be drawn in straight, hard lines, as such lines are decidedly unnatural and produce a crude effect. They should show stream character. The course of a river may be straight in general, but it is likely to be somewhat sinuous in detail and suggest (even if not shown) a gradual widening from source to mouth. On small-scale maps where the eye can encompass a stream through its full length, its imperceptible widening can be expressed by a line of almost uniform weight except for the stretch near its source where it should grow thinner and taper off. Otherwise the stream may print heavier at its source. On maps which are to be reproduced directly from drawings in black and white and upon which both relief contours and drainage lines are shown, the lines representing the streams and other water bodies should be drawn freehand and slightly heavier than the contour lines, which should be sharper and more precise.

The names of all streams or other bodies of water should be in italic letters, those of the larger streams being lettered in capitals and those of the smaller streams in capitals and lower-case letters (see §§37–39).

Water-lining.—Water-lining should be limited to maps on which the water areas are not readily distinguishable from the land areas. In rough drawings that are to serve only as copy for stone or wax engravings a flat color may be used for water areas and its conversion into water lines specified. In base maps to be reproduced in three colors a light-blue tint may be used in lieu of water-lining, and it can be printed either flat or in a fine ruling transferred to the stone that is to print the streams. The engraving of water lines is expensive, and the flat tint or reticle is generally preferred.

Water-lining on finely engraved and large maps sometimes consists of 30 to 45 lines, but on small maps and sketch maps the number may be reduced as desired. Care should be taken that the lines are as nearly parallel as they can be made freehand and of even weight or thickness. The first three to six lines outside the coast line should be somewhat closer together than

those farther out and should conform closely to the coast line, but the spacing between the lines should increase and the lines should become almost imperceptibly less conformable to the coast line as they reach their outer limit, the last three to six being made with the greatest care and refinement. Water-lined maps that are to be reproduced by photographic processes should be drawn at least twice publication size. The reduction will bring the lines closer together, and the reproduction will thus show a more refined effect than could possibly be produced by the most skillful exact-size drawing.

Good examples of water-lining should be studied by draftsmen before they undertake such work.

§36. Cultural Features

Cultural features represent not only "the works of man"—cities, towns, buildings, bridges, railroads, and other roads—but state, county, and other boundary lines, in short, all that part of a three-color base map which is printed in black. The engraved plate for the black is called the "culture" plate as distinguished from the "drainage" and the "relief" plates.

Following is a list of the cultural features referred to. See Plate XIV for symbols.

Aqueduct mains	Electric power lines	Oil wells
Aqueduct tunnels	Fences	Open cuts
Bench marks	Ferries	Park boundaries
Boundary lines	Fords	Paths
Boundary monuments	Gas wells	Pits
Breakwaters	Hedges	Post offices
Bridges	Forts	Precinct lines
Buildings	Hospitals	Prospects
Cable lines	Jetties	Province lines
Camps	Land-grant lines	Quarries
Canal locks	Land-section lines	Railroads, steam or electric
Canals	Levees	Ranches
Cemeteries	Mains	Reservation boundaries
Churches	Mineral monuments	
Cities	Mine tunnels	Reservoirs
County lines	Mines	Roads
Dams	National forests	Ruins
District lines	National parks	Schoolhouses
Ditches	Oil tanks	

Section corners	Towns	Tunnels
Section lines	Township corners	Villages
Settlements	Townships	Water mains
Shafts	Trails	Water wells
Streets	Tramways	Waterworks
Telegraph lines	Triangulation stations	Windmills

The styles of lettering used for cultural features, including both civil divisions and public works, are given in §37.

§37. Lettering by Hand

Sizes of letters.—When a map is lettered the size of the letters depends, first, upon the reduction that will be given the map when it is reproduced. For example, if the map is to be reduced one-half, all the letters should be twice publication size, i.e., the smallest letters not less than two millimeters in height; at the same time the relative differences in size or prominence of certain features should be maintained. For the purpose of gauging the size of letters, the minimum height of the smallest letter in the printed illustration should be one millimeter; and this measure should be the basis upon which all the reductions are figured.

It is also important that accurate guidelines be used in drawing letters. For this purpose railroad pencils are indispensable, since a slight variation in the width of a space will be very noticeable in the size of the letters. Thus the size of letters should be made to indicate in a general way the relative importance of a feature or group to which they are applied. On some maps the county seats, state capitals, and large cities may be distinguished by different symbols. And the names of civil divisions are lettered in sizes depending on their relative grade and the size of the area or space in which the names will appear.

Many treatises on lettering have been published, and the essential principles of the art are generally well understood by most draftsmen. The correct form of each style of letter, spacing, and other essential points, can be learned from such treatises, but proper display and arrangement are best learned by observation and experience. Good lettering is passed without

notice; but slight imperfections of form, spacing, slant, shading, and, above all, lack of legibility, will be quickly detected and criticized. Map letterers should note that the name of a place or the number of a symbol should be put to the right of the symbol if possible and a little above or below it—not to the left and directly on a line with it, as "Tucson o," "17 o," "Dallas o," "Carson o," which is sometimes misleading. Moreover, names indicating large areas, if written from west to east, should curve with the parallels, and all names should be so lettered that "if they should fall they would fall on their feet." Every name should be distinctly legible but not too conspicuous. Lines should be broken in order to make the lettering clear except where there is no possible danger of smudging, in which case the lines are run through. The lettering on a map should always be so spaced that it will properly fit the area it is intended to designate. When it consists of two or more words the letters should be spread and increased spaces left between the words. In numbers, except those used to indicate elevations on contour lines or elsewhere, thousands should always be set off by commas.

Draftsmen often err in drawing commas, quotation marks, apostrophes, and question marks. The following forms are correct:

Comma ,	Apostrophe '
Quotation marks " "	Question mark ?

Kinds of letters.—The features shown on a topographic map may be broadly separated into four groups and are lettered as follows:

Civil divisions (countries, states, counties, townships, land grants, reservations, cities, towns, villages, settlements, schools, lodges, ranches, etc.), Roman capitals or capitals and lower case.

Public works (railroads, tunnels, roads, canals, ferries, bridges, fords, dams, mains, mines, forts, trails, etc.), slanting Gothic capitals (light) or capitals and lower case.

Hydrographic features (oceans, seas, gulfs, bays, lakes, ponds, rivers, creeks, brooks, springs, wells, falls, rapids, marshes, glaciers, etc.), Italic capitals or capitals and lower case.

Hypsographic features (mountains, ranges, peaks, plateaus, cliffs, buttes, canyons, valleys, peninsulas, islands, capes, etc.), upright Gothic capitals (light) or capitals and lower case.

A A A A 1 1 1 1 1 1 a a a a a a
B B B B B 2 2 2 2 2 2 b b b b b b
C C C C C 3 3 3 3 3 3 c c c c c c c
D D D D 4 4 4 4 4 4 d d d d d d
E E E E E 5 5 5 5 5 5 e e e e e e e
F F F F F 6 6 6 6 6 6 f f f f f f f
G G G G 7 7 7 7 7 7 g g g g g g
H H H H 8 8 8 8 8 8 h h h h h h

16 Pt.

A A A A A 1 1 1 1 1 1 1 1 a a a a a a a a
B B B B B B 2 2 2 2 2 2 2 2 b b b b b b b b
C C C C C C 3 3 3 3 3 3 3 3 c c c c c c c c
D D D D D 4 4 4 4 4 4 4 4 d d d d d d d d

14 Pt.

A A A A A A 1 1 1 1 1 1 1 1 a a a a a a a a
B B B B B B 2 2 2 2 2 2 2 2 b b b b b b b b
C C C C C C 3 3 3 3 3 3 3 3 c c c c c c c c c
D D D D D D 4 4 4 4 4 4 4 4 d d d d d d d d

12 Pt.

A A A A A A A 1 1 1 1 1 1 1 1 1 a a a a a a a a a a
B B B B B B B 2 2 2 2 2 2 2 2 2 b b b b b b b b b
C C C C C C C 3 3 3 3 3 3 3 3 3 c c c c c c c c c c
D D D D D D D 4 4 4 4 4 4 4 4 4 d d d d d d d d d

10 Pt.

A A A A A A 1 1 1 1 1 1 1 1 1 1 a a a a a a a
B B B B B B 2 2 2 2 2 2 2 2 2 2 b b b b b b b
C C C C C C 3 3 3 3 3 3 3 3 3 3 c c c c c c c c
D D D D D 4 4 4 4 4 4 4 4 4 4 d d d d d d d
E E E E E E 5 5 5 5 5 5 5 5 5 5 e e e e e e e
F F F F F F 6 6 6 6 6 6 6 6 6 6 f f f f f f f f

8 Pt.

Sheet showing reference letters and numbers printed from type

§38. Lettering by Use of Type

Method used.—Much of the lettering now used on illustrations is printed from type on white paper which is cut out and pasted in its proper position on maps or other drawings. The lettering on Plates XIV, XV, XVI, XX, and XXI was prepared in this way. The best results can be obtained by having the type printed on a special brand of "non-curling" gummed paper, from which the lettering is cut in squares or strips, dampened, and applied to the proper places on the drawing. A pair of dentist's tweezers with curved points is almost indispensable in handling the paper strips. When too much mucilage is applied to ordinary paper the moisture may cause the paper to warp or curl, and this can seriously affect the reproduction of the drawing. This printed lettering is used, however, only for headings, titles, notes, and other matter that stands alone; it is not generally used for the geographic names in the body of a map, unless only a few names are to appear.

The reproduction of printed letters by photoengraving or photolithography gives results superior to those obtained from hand lettering unless each letter is made with the utmost care—work which is considered a waste of time unless there is difficulty in finding a printing office equipped with suitable type and facilities for providing clean sharp prints.

For reference numbers and letters to be used on groups of figures, or on plates after they have been made up for reproduction, those shown on Plate XVII are appropriate and are much used. They are shown on this plate in graded sizes from 8-point to 16-point Roman type. The smaller sizes should be used on illustrations that are to have no reduction. Where there is occasion to use such lettering, those shown can be furnished in sheets by any well-equipped printing house. They should be printed on smooth, pure white paper.

The method of placing the lettering on a drawing is as follows: First cut out in squares the numbers required for one illustration; then, with a pair of dentist's tweezers pick up each letter and dip it in mucilage; now rub off the superfluous mucilage with a finger and place it in position; after this has

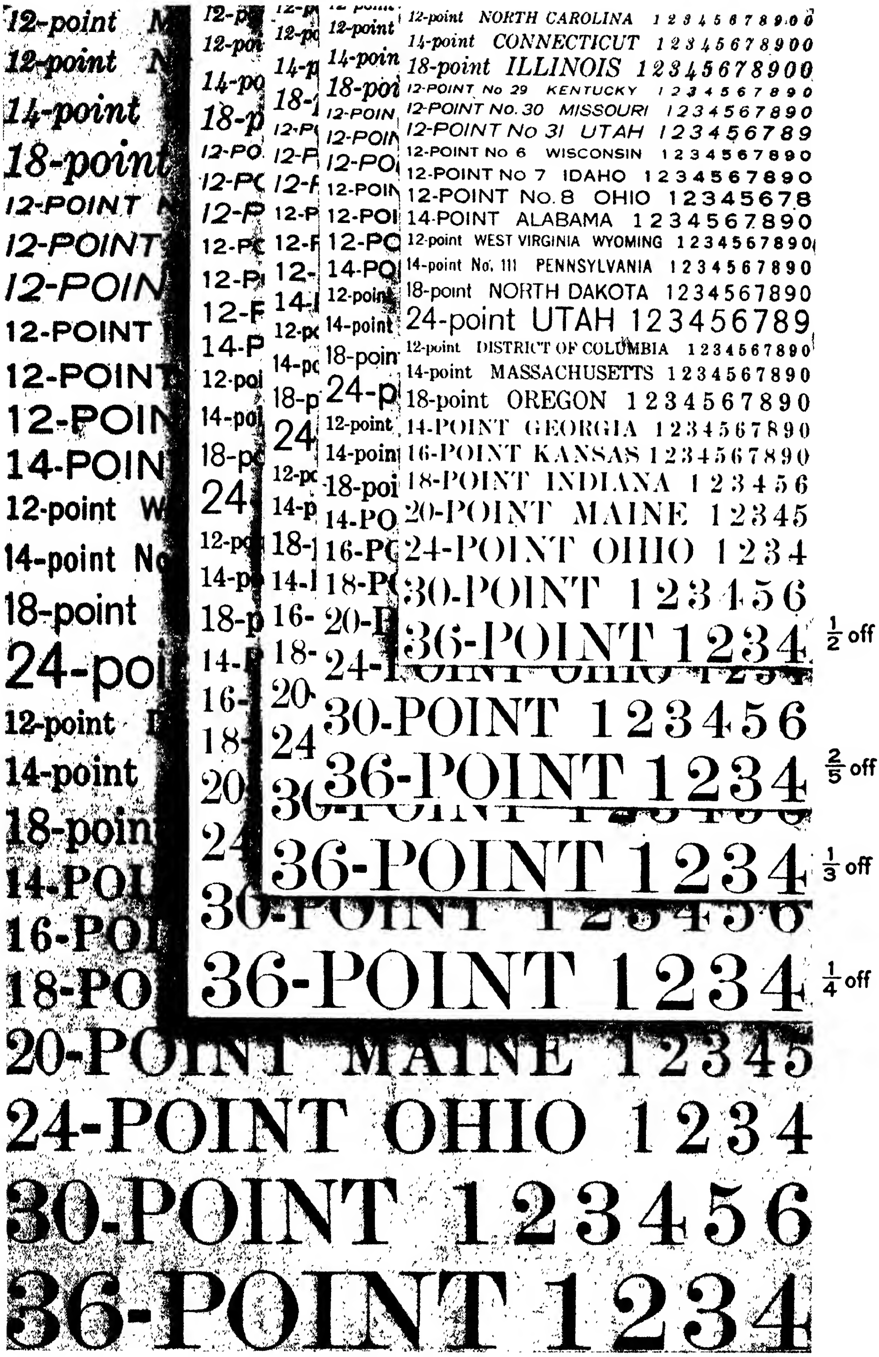
been done, adjust the letter or number into an upright position and press it down with a clean blotter. The printed result will be far more satisfactory than hand lettering.

Style and size of type.—Plate XVIII shows most of the styles and sizes of type appropriate for use on illustrations. Where a drawing is to be reduced one-half the smallest letter should be 2 millimeters in height; if it is to be reduced one-third the smallest letter should be about 1.5 millimeters in height; and so on. No letter whose height after reproduction would be less than one millimeter should be used, and the larger lettering should bear a proper relation to the smaller. In preparing Plate XVIII a much larger sheet, upon which the various styles and graded sizes of type had been printed, was cut to the size of a full-page plate. The sheet was then photographed four times, each time with the reduction indicated on the margin, and the reduced sheets were pasted on as shown. If a drawing is to be reduced one-half, for example, the sheet that has been reduced one-half will show the size of the lettering on the printed plate so that by referring to the sheet showing the reduction desired the letterer can select type of a size that will be legible.

§39. Mechanical Lettering

A number of methods of supplying lettering on illustrations by mechanical devices are procurable. With practice some of them produce satisfactory results. Among them is a method known as the Leroy Lettering System, another as the Wrico Lettering Guides, and still another called the Ames Lettering Device, which allows the user to vary the heights of letters by adjustment and the slope or slant without adjustment of parts.

When any particular style and size of lettering is not deemed important or necessary, as for example the lettering on simple outline maps, small charts, and other illustrations that are more or less diagrammatic, any one of these mechanical devices is useful and, if the letters are of proper size, they produce results far better than lettering made by persons unskilled in the art. Reduction of all lettering should be based upon a height of



Reduction sheet useful in lettering drawings (see p. 102)

one millimeter as representing the minimum size of the smallest type, for clear legibility.

§40. Abbreviations Used on Maps and Illustrations

The abbreviations given in the following pages are inserted only because they have been found to include those most often needed in preparing miscellaneous drawings. The list will be found to have a direct bearing on the matter contained in this book and is included for convenient reference. It is intentionally far from a complete list.

The following abbreviations are used on maps:

A.	Arroyo	L.H.	Lighthouse
B.M.	Bench mark	Long.	Longitude
Bdy.	Boundary	M.P.	Milepost
Br.	Branch, Bridge	M.M.	Mineral monument
C.	Cape	Mt.	Mount
Can.	Canal, Canyon	Mtn.	Mountain
Cem.	Cemetery	Mts.	Mountains
Co.	County	N.	North
Cr.	Creek	Pen.	Peninsula
E.	East	Pk.	Peak
El.	Elevation	P.O.	Post office
Est.	Estuary	Pt.	Point
Fk.	Fork	R.	Range, River
Ft.	Fort, Foot	Res.	Reservation, Reservoir
Gl.	Gulch, Glacier	R.H.	Road house
Hbr.	Harbor	S.	South
I.	Island	Sd.	Sound
Is.	Islands	S.H.	Schoolhouse
Jc.	Junction	Sta.	Station
L.	Lake	Str.	Stream
Lat.	Latitude	T.	Township
Ldg.	Landing	Tps.	Townships
L.S.S.	Life-saving station	Tel.	Telegraph
		W.	West

Such words as "mount," "river," and "point" should not be abbreviated where they form a part of the name of a city or town, as "Rocky Mount," "Fall River," "West Point." Neither the word nor the abbreviation for railroad or railway should be placed on a map; the chartered name (or initials of the name) and the road symbol are sufficient.

Names of states and territories are abbreviated, where abbreviation is necessary, as follows:

Ala.	Ga.	Minn.	N.J.	Tenn.
Ariz.	Ill.	Miss.	N.Mex.	Tex.
Ark.	Ind.	Mo.	N.Y.	Va.
Calif.	Kan.	Mont.	Okla.	Vt.
Colo.	Ky.	Neb.	Ore.	Wash.
Conn.	La.	Nev.	Pa.	W.Va.
D.C.	Mass.	N.C.	R.I.	Wis.
Del.	Md.	N.Dak.	S.C.	Wyo.
Fla.	Mich.	N.H.	S.Dak.	

The following names should be written in full:

Alaska, Guam, Hawaii, Idaho, Iowa, Maine, Ohio, Samoa, and Utah.

The abbreviations used on the margins of maps for subdivisions of land should be as follows (note punctuation): T. 2 N., R. 3 W. On large scale plats the marginal lettering should be as follows: N. ½ NE. ¼ sec. 1, T. 7 N., R. 2 W.; fractional secs. 2 and 35, Tps. 7 and 8 N., R. 2 W.; NW. ¼ sec. 20, T. 7 N., R. 2 W. In spelling fractions, use half and quarter, not one-half and one-quarter.

The abbreviated forms of such names as "North Fork" and "South Fork" should be "N. Fork" and "S. Fork," not "North Fk." and "South Fk."

Additional abbreviations used on illustrations, particularly sections and diagrammatic figures, are as follows:

N. for north, NE. for northeast, NNE. for north-northeast, etc. Capitalize directions affixed to street names, as N.W., S.E. (521 Sixth St., N.W.).

Sec. and secs. for "section" and "sections" before a number. Capitalize only at the beginning of a sentence.

Use a.m. and p.m. for antemeridian and postmeridian, as 4:30 p.m. Lowercase unless in line of caps.

Use & in names of corporations or companies. On all miscellaneous maps "and" is spelled out in railroad names.

B.t.u.—British thermal units.	dwt. or pwt.—pennyweight.
bbl., bbls.—barrel, barrels.	oz.—ounce or ounces.
bu.—bushel or bushels.	etc. (not &c.)—et cetera.
c.c.—cubic centimeter.	ft.—foot or feet.
mm.—millimeter.	h. m. s.—hours, minutes, and seconds.
cm.—centimeter.	in.—inch or inches.
cwt.—hundredweight.	

kw.—kilowatt or kilowatts.
£. s. d.—pounds, shillings, and pence.
per cent (omitting the period)—per centum. Spell out percentage.
ser.—series.
St.—Saint or Street.
U.S. Army—United States Army, as distinguished from United States of America (U.S.A.).
yd., yds.—yard, yards.

The names of certain months may in some places be abbreviated; those of others should invariably be spelled out. The following are the correct forms used most often in the preparation of statistical diagrams, graphs, and curves:

Jan.	Apr.	July	Oct.
Feb.	May	Aug.	Nov.
Mar.	June	Sept.	Dec.

The proper abbreviations for number and numbers before figures are "No." and "Nos." The *o* should never be raised as in N^{o}. The abbreviation for "Mac" is "Mc," not "M^{c}."

It is important that periods be consistently omitted from abbreviations used in the body of a map unless their omission would cause misunderstanding. They are generally unnecessary and if used are likely to be mistaken on some maps for symbols representing certain features, such as houses or flowing wells, if either are shown. Periods used on drawings other than maps that are to be reproduced "direct," or photomechanically, should always be slightly exaggerated.

Names of railroads.—Railroad names may be written in full or abbreviated in accordance with the kind of map and the space available. On the smaller black-and-white maps the initial letters are generally sufficient. On more detailed maps, if there is room, the names may be spelled out. As already stated, neither the words "railroad" and "railway" nor the abbreviations "R.R." and "Ry." should be used on a map, as the symbol for railroad is a sufficient identification.

§41. Copying or Transferring

Tracing.—Probably the oldest and best-known method of copying a drawing or other matter and transferring it to another

sheet is by the use of tracing paper. This method, though still used for simple work, has given way to quicker and more effective methods. By one of these methods a piece of thin, fairly smooth paper is coated with graphite by rubbing over it a soft pencil. When the graphite has been evenly distributed the sheet is laid upon the drawing paper, coated side down, the subject to be copied is laid upon the graphite-covered sheet, and the two outer sheets—the drawing paper and the map or other subject—are securely fastened together. The outlines of the matter to be copied are then firmly and carefully traced with a steel tracing point or very hard pencil and thus transferred to the clean drawing paper beneath.

For tracing maps that show several features in different colors, sheets rubbed with blue, orange, brown, or green pencils may be used, one after another, for tracing each set of features. Red should not be used, as it is not easily erased. This method insures distinctive lines for the separate features and prevents the confusion that might result from the use of one color only. Exact register of the features shown in the several colors used may be insured by fastening one edge of the drawing to be copied to the drawing paper by adhesive tape, mucilage, or thumbtacks. The colored sheets may then be slipped in and out without altering the position of the lines or symbols for one set of data with relation to those for the others.

In the final preparation of a base map to be engraved and printed in colors—for example, black, blue, and brown—tracings of the three colors appearing on the original base should generally be transferred, as described above, to one sheet of paper and thus worked up into a three-color map. It is usually unnecessary and undesirable to draw each color on a separate sheet. The preparation of separate drawings may facilitate reproduction, but if they are made on tracing cloth the usual uneven shrinking or stretching of the cloth may produce misregister in the printing; therefore it is safer to make a single drawing, so that the photolithographer can make three negatives and separate the colors by painting out or "opaquing" the colors not wanted on each negative. A map drawn on a single sheet is

also less bulky and can therefore be more conveniently handled and compared with proof.

If for any reason it is considered desirable to make separate tracings for the different colors on a map, they should be made on linen cut from one roll and in the same direction according to the warp and woof.

The "Shadowless" drafting table.—A useful and almost indispensable contrivance for tracing a drawing on its same scale is called by its manufacturers the "Shadowless" drafting table, though one may easily be constructed. It is needed in every office in which drafting is done and has been found to be a convenient addition to any scientific laboratory. Its essential features are a wooden, box-like table inclosing strong incandescent lights and bearing a ground plate-glass top. A drawing placed on the ground glass will be so illuminated as to make its lines conspicuous and readily traceable even through relatively thick paper. The table is particularly useful for tracing sheets upon which the lines are indistinct and would not be discernible under tracing paper with reflected light. It is also useful in preparing drawings in which certain features must register perfectly over each other. In fact, any drawing that does not require enlarging or reducing can be traced with great facility by the use of this drafting table, and it is particularly useful for tracing faint lines on old and poorly preserved prints or drawings.

Copying by co-ordinate squares.—If there is no objection to marring a sheet bearing the design or matter to be copied, it may be ruled lightly into pencil squares of equal size. Corresponding squares of the same size, larger, or smaller, according to the size of the new drawing, are then ruled on the drawing paper, and the work is sketched in square by square. If it is important that the original sheet be not marred, the same result can be obtained by drawing the lines on a transparent oversheet. This method is serviceable for enlarging or reducing simple work that includes no great amount of detail; if great precision of detail is required, the original should be enlarged or reduced by photography or by the pantograph.

Celluloid transferring.—The celluloid method of transferring a map or parts of a map to paper upon which a complete new map is to be drawn is much used by lithographers. In using this method the map or any part of the map to be copied is photographed to the exact scale of the new drawing and reproduced in graphite on thin sheets of celluloid by photolithography. The celluloid sheet is then laid face down in its correct position on the drawing paper and firmly rubbed on the back with a steel burnisher, which makes a perfect offset of the map on the paper. After the parts desired are inked over, the superfluous graphite is easily erased with an ordinary rubber.

By using this method (for which it is necessary to be in touch with a lithographer) it is possible to get absolute scale and more satisfactory results than by tracing over a photographic print line for line or by using a pantograph.

Pantograph in map drawing.—As stated in §14 the use of the pantograph has been directed more to enlarging and reducing maps or parts of maps to scale than to using it simply as a means of copying maps on the same scale. By its use, however, the expense of photography is saved. In its absence the ordinary tracing-paper method described above in this section is recommended.

§42. Distinguishing Areal Patterns for Black-and-White Maps

The conventional patterns used on maps and many other subjects to distinguish the separate areas are shown in Figure 14. The patterns represent combinations of lines, dots, and other forms, and are spaced openly or closely according to the size of the area to be covered, the contrast needed between areas, and the general clearness and effect desired. If a map, for example, is to show both small and large areas, dense or closely spaced patterns should be used for the smaller areas, even if they may be required for some fairly large areas representing the same data or condition. On the other hand, open patterns should be used for large areas. Again, it may be necessary to make certain areas more conspicuous than others, and this needed contrast can be best produced by drawing the lines closer together

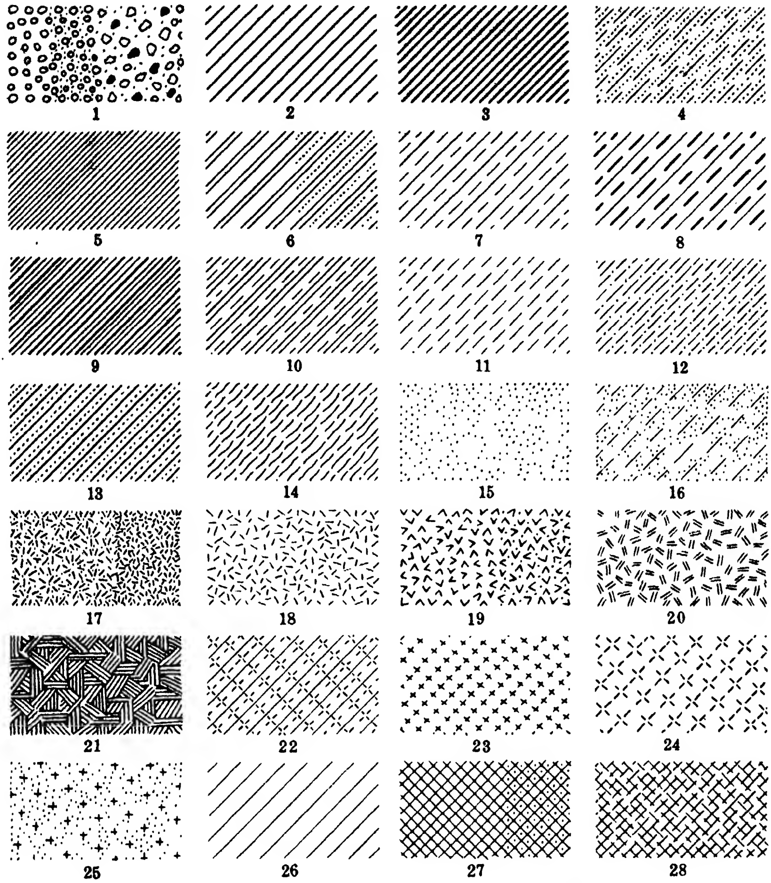


FIG. 14.—Distinguishing areal line patterns

rather than by making them heavier, unless the area to be covered is small. Heavy line patterns or bars are not desirable. The lines forming a pattern should be drawn at an angle of 45° to the sides of the plate; they should be drawn vertically or horizontally only in small areas or in areas not crossed by meridians or parallels on a map, or by other lines running in the same direction. The lines should run across the long axis of an area, not parallel with it, and the predominating trend or general direction of the areas of one kind of data should decide the direction of the lines for all areas of the same kind on the same drawing, even if the rule must be violated on some minor areas. Any conventional pattern that is used should be subordinate in

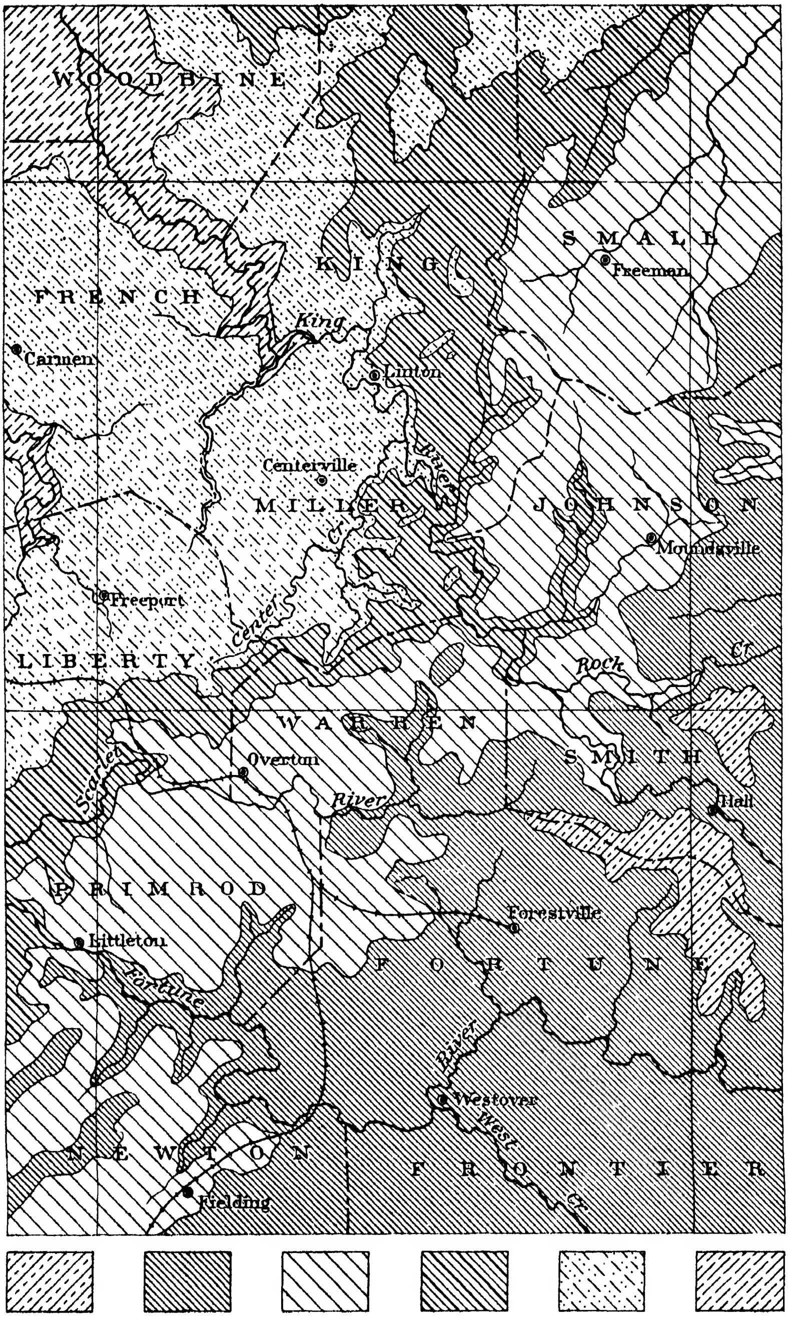


FIG. 15.—Map bearing six areal line patterns

strength to the main features of the illustration on which it is drawn. On black-and-white maps, as in colored maps, for example, unlike patterns should be placed next to each other and the lines made to follow the same direction in order to obviate a herringbone effect which is particularly objectionable. A section liner or other ruling device is useful in drawing line patterns, by which uniformly even spacing can be produced. The application of six of these conventional patterns to a base map is shown in Figure 15. Note direction and weight of lines.

For preliminary maps water colors or crayons can be used instead of ruled tints, but the areas should be further identified by a legend or key, so that distinctive patterns can be substituted in the final preparation.

§43. Coloring Preliminary Maps

It is of no particular importance whether or not the colors used on the maps prepared by an author are pleasing, but it is important that they give clear distinctions. The separate areas should be so colored that they can be identified or distinguished with certainty. Some water colors are fugitive and when laid on in light tints they disappear entirely or become uncertain. The greatest difficulty, however, is due to promiscuous mixing of colors. It is well known that many persons cannot match or discriminate mixed colors. Hence, if the supply of a color produced by mixing becomes exhausted, and the attempt is made to duplicate it by a second mixture, the two will probably fail to match. It is therefore recommended that water colors in full strength, and the same colors diluted to half-strength be used instead of mixtures of two or more pigments, so that one color in two strengths or tones can be employed to indicate two areas that are to be distinguished.

Selected water colors.—The colors listed below will give 22 satisfactory distinctions without admixture and will thus supply all demands for map coloring:

Mauve	Cadmium yellow	Payne's gray
Crimson lake	Chrome yellow	Lampblack
Orange-vermilion	Olive green	Sepia
Burnt sienna	Hooker's green No. 2	

Since it is important that contrasts between colored areas on a map be maintained, unlike colors should be placed next to each other—that is, colors should be placed together that are widely separated in the spectrum, such as yellow and purple, red and green, blue and orange, burnt sienna and olive green; not such as red and orange, blue and violet, orange and yellow, sepia and burnt sienna.

How to apply.—After a sufficient quantity of water and color pigment to cover an area has been mixed, it should be stirred in a saucer until the desired strength or tint is produced before it is applied. To maintain the same tone properly the color should be well stirred every time the brush is filled; if it is not stirred, the brush will on each successive dipping take up a lighter tint, because most pigments, especially those derived from minerals, tend to precipitate. When the colors are applied, the map should be placed in a slightly inclined position, and the coloring should be started at the upper boundaries of an area, the well-filled brush being pulled toward the painter and worked rapidly back and forth horizontally while the fresh color is wet. If the edges are allowed to dry they will present a harsh and uneven effect.

Full and fairly strong color should be used for small areas, unless the map shows also large areas that require the same color; lighter hues should be used for large areas. In geology bright colors are best suited for areas of igneous rocks, dikes, and veins, and these may be reduced in strength for larger areas.

The standard color scheme for geologic maps (see §44) need not be applied in the early stages of preparation, except in the most general way. Appropriate final colors can be best selected when the new map is made ready for engraving. In the author's original maps adequate color distinctions between areas, if made with unmixed colors as suggested, are more important than the use of standard geologic colors. Patterns should not be ruled on preliminary maps to indicate distinctions between different formations of the same age or period, because such patterns are more difficult to produce by hand than by engraving; besides, they are not necessary.

As stated in §28, it is of vital importance that an original base map should be free from colors and from technical symbols in order that it may be kept clean for photographing and be preserved for possible future use. Such a map should preferably be photographed in order to obtain prints on which to add the colors and symbols; the use of an oversheet for this purpose is not nearly so satisfactory. When photographed, the base map can be reduced to publication scale in order to save the additional cost of a larger negative. The print should be unglazed, so that colors and symbols, title, explanation, etc., may be added; but the lithographer will also need the original base map from which to make his reproduction.

Use of colored crayons.—Colored pencils and crayons are sometimes preferred for coloring preliminary maps because they are more easily handled than water colors. They are not, however, entirely suitable for coloring maps that are retained only for record. When a map that is to show distinctive areas is prepared for the lithographer, colored crayons have been found to produce satisfactory results if by their use proper contrasts are maintained. As already stated, the colors should be added to a reduced and unglazed photographic print of the base map, or, if photographing is not practicable, to the unglazed side of tracing linen, which will serve as an oversheet. If the latter is used, register marks should be added at the four corners and at other parts to insure the fitting of the colors with the base map.

Each area should be colored with a separate crayon. Patterns or designs should rarely be used except to strengthen contrasts, and this may be accomplished by adding a freehand pattern with a black pencil over a color to make the area still more distinctive.

Use of Japanese transparent water colors.—The so-called Japanese transparent water colors have been used successfully by some authors in preparing their original maps. They spread evenly and are convenient for field use; but they cannot be washed out like other water colors, so that when they are once applied to an area and a change of color becomes necessary

they must be bleached out. A good bleach is sodium hypochlorite, which should be applied with a brush until the color disappears; the area can then be dried with a blotter before recoloring. Light tints of these colors are believed to be somewhat fugitive when exposed to strong light.

§44. Standard Colors for Geologic Maps

A standard color scheme for systems of sedimentary rocks is used on the maps in the geologic folios of the United States Geological Survey and should be in general use elsewhere. It is, however, subject to some modification where used on miscellaneous maps in other publications. Each system is represented by a different color, and if there are two or more formations in one system they are generally distinguished by using different patterns composed of straight parallel lines in the same color. The patterns for subaerial deposits (chiefly Quaternary) are composed of dots or circles, or combinations of both, and may be printed in any color; but the color most often used is yellow or ochraceous orange. No specific colors are prescribed for igneous rocks, but they are generally more brilliant than those used for sedimentary rocks. For small areas, igneous colors are used "solid"; for large areas the same color is diluted and reduced in tone, or a suitable cross-line pattern or reticle is used. Metamorphic rocks are represented by short dashes irregularly placed. These dashes may be in black or in color over a ground tint or pattern.

The standard colors used for the sedimentary series covering the twelve systems now recognized are the following: Quaternary (Q), *ochraceous orange*; Tertiary (T), *yellow ochre* and *isabella color;* Cretaceous (K), olive green or *rainette green;* Jurassic (J), *blue-green* or *niagara green;* Triassic (TR), light peacock blue or *bluish gray-green;* Carboniferous (C), blue or *columbia blue;* Devonian (D), gray-purple or *heliotrope-gray;* Silurian (S), purple or *argyle purple;* Ordovician (O), red-purple or *rocellin purple*; Cambrian (Є), brick red or *etruscan red;* Algonkian (A), terra cotta or *onion-skin pink;* Archean (AR), gray-brown or *drab.**

* Names printed in italic are from Robert Ridgway, *Color Standards and Nomenclature.*

§45. Marking Reduction or Enlargement of Maps

A simple, accurate method of marking the reduction or enlargement of a map to any selected scale is shown in Figure 16. Measure the distance between the extreme meridians along one of the parallels. Convert this distance into miles by multiplying the number of degrees it covers (say 3) by the numbers of miles in a degree. A degree on the forty-third parallel, for example, is 50.669 miles (see Appendix Table II, p. 152), which multiplied by 3 equals 152.007 miles. Then draw a line on the margin of the map, outside the border, the exact length of the 3 degrees, and just below this line draw another line representing the same number of miles (152.007) on the scale to which the map is to be reduced or enlarged. Then mark to reduce or enlarge the upper line to the lower line, as shown in the figure. A long line will reduce error and give greater accuracy than a short one, and therefore as great a distance should be set off as possible. The number of miles represented by both lines and the fractional scale to which it is to be reduced should be stated on the drawing, for record.

Maps that will bear reduction without affecting clearness of details may also be reduced arbitrarily to fit the book in which they are to appear, regardless of definite fractional scale. The reduction for such maps is best marked in fractions, as "⅓ off," "⅖ off," "½ off," "⅗ off," "⅔ off," etc. If the size needed is not exactly represented by these fractions, it can be indicated in inches; as: "Reduce this line to 7½ inches" or "Reduce to 4⅜ inches in width." Every map should show a bar scale before it is photographed.

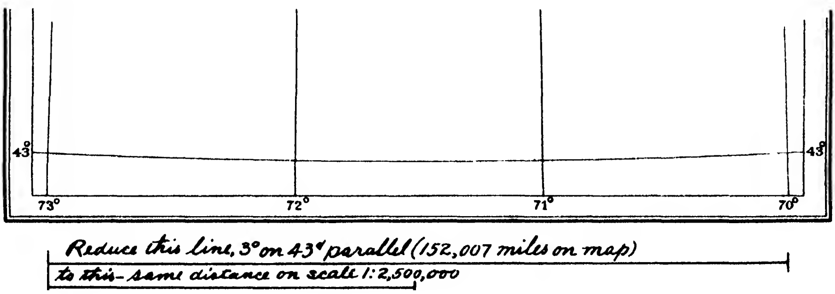


FIG. 16.—Diagram showing method of marking maps for reduction or enlargement to scale.

§46. Diagrammatic Illustrations

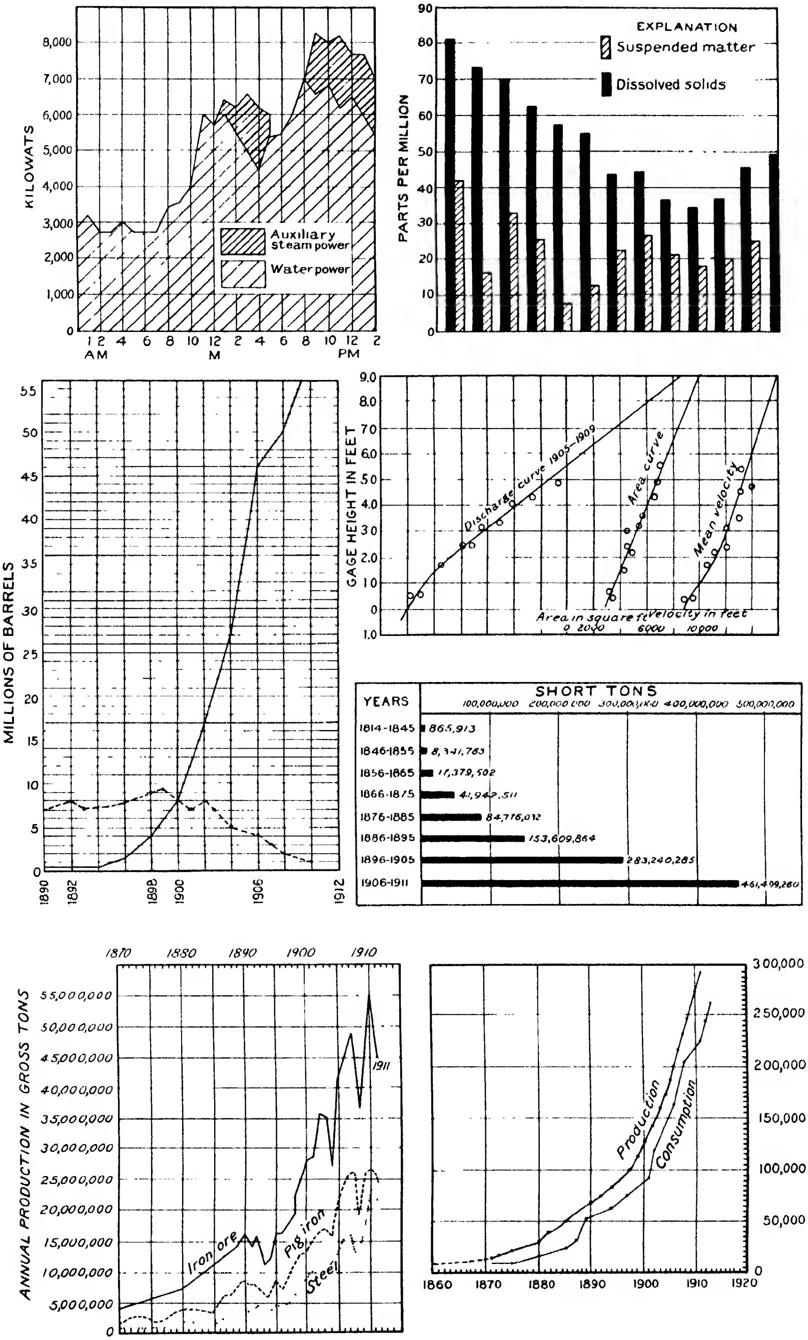
Author's preparation.—Essentially the most important point in drawing original diagrams is clearness of copy. Although the subject may be a simple one, that fact should not warrant hasty preparation, for a rough draft or a sketch that has been carelessly worked out and is inaccurate or inconsistent in detail may lead to serious errors. For plotting profiles and structure sections, ruled paper printed in blue or orange lines should be used. Curves or other data made with pencil by an author on the blue-lined section paper may be inked in by a skillful draftsman. An author's sketchy pencil drawing can be followed if it indicates clearly enough the facts to be represented; but stereograms and block diagrams should be prepared originally by an author with especial care in order that his viewpoint may show clearly in his sketch and thus be imparted graphically to the draftsman.

For illustrations of apparatus, photographs are preferred; but if rough sketches are submitted they should show correct relations and have all dimensions plainly indicated.

Final preparation.—In the final preparation of a diagram the draftsman should endeavor to make every part and relation perfectly clear to the reader by rendering good clear lines. He should study the author's original copy until he fully understands its purport and can redraw it simply and legibly. Any lettering that may be needed should generally be in plain upright or slanting Gothic type (see Plate XIX). When a diagram consists of one bar or a series of very wide bars, solid black should be avoided. Ruled or fine cross-line tints give a better effect. Solid black areas, if large, render too great a contrast with other parts of a drawing; besides, they do not always print evenly.

A diagram to be made for book illustration should generally be drawn twice publication size on Bristol board or on the section paper already referred to, and should be marked for reduction to the width of the text. It should bear no title, as the title and other outside descriptive matter will be set up in type by the printer. Plate XIX shows a number of types of diagrams, each with the position, size, and style of lettering it generally requires.

PLATE XIX



Graphs and curves to show arrangements of lettering and general style of drawing

Block diagrams.—The purpose of block diagrams is described by Lobeck in his textbook,* in which will be found numerous examples showing their application in bringing out various types of geologic and physiographic structure. The subject is exhaustive and requires more than the brief treatment afforded in this book, which pertains essentially to the perspective development of the block—that is, to the construction of a block or cube, which, after all, serves only as the framework upon which the scientific data may be properly represented.

It should be understood that the preparation of a block diagram requires a certain facility of execution dependent upon a clear conception of the problem and upon its successful development, since the great utility in a block diagram rests in the ease with which one may observe at a glance two distinctly related features, both being complete in themselves yet tied together into a single unit. This, however, is no more difficult than the representation of the topography in a perspective drawing *without* the underlying features, to do which the ability to sketch true spatial relations in a natural way is all-important.

Simplicity is the keynote in all block diagram drawing in which only the elements needed to demonstrate important facts and relations are presented. Perspective in the simpler kinds is only suggested by having the sides of a block vanish to some distant point in order to produce the effect of foreshortening. It is, however, highly important that the optical principles of linear perspective as applied to a block or cube be well understood so that they can be more readily applied to freehand work. To produce a simple block strictly in accordance with the rules of true linear perspective would require much time in preliminary work.

Two methods are commonly used in representing a block. One is known as one-point or parallel perspective, in which one set of lines vanish to a distant point on the horizon and the other lines are vertical and horizontal. The other is known as two-point or angular perspective, in which the front corner of the

* Armin Kohl Lobeck, *Block Diagrams and Other Graphic Methods Used in Geology and Geography,* John Wiley & Sons, New York, 1924.

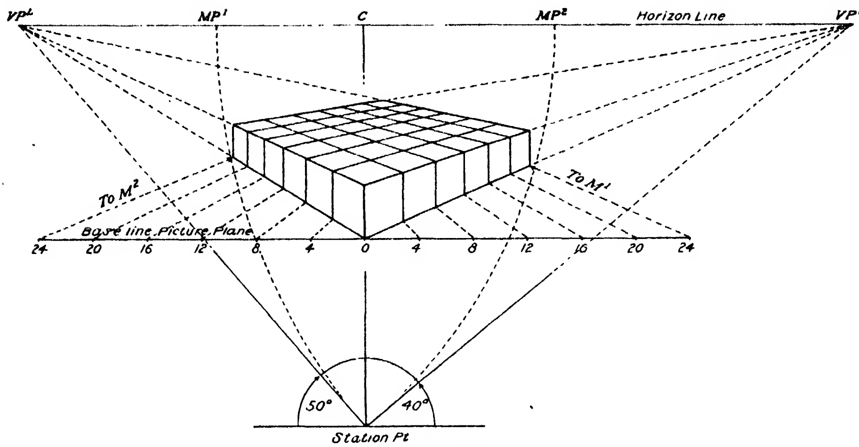


FIG. 17.—Diagram showing the perspective development of a block according to scale, and the location of vanishing points, measuring points, and their uses.

block faces the observer and both sides vanish to opposite points on the horizon, the block being placed within the picture plane.

Construction of a true block.—The method of representing a block in three dimensions may be based upon certain principles of perspective which depend on one vanishing point for each system of parallel lines in an object, as shown in Figure 17.

It may be observed here that all lines which are at right angles to the plane of the picture must converge to the center of vision, and that all lines which in an object are parallel to each other vanish in the same point as best shown in Figure 8.

As all projections are based on a perfectly level plane, any deviation from that plane will necessarily move the vanishing point directly above or below the point already established on the horizon.

When a perspective view is prepared it must be known that the horizon is always level with the eye; hence, when raised, the field of vision is extended and, when lowered, the field becomes narrower. Therefore in sketching a block it may be necessary to reduce or increase the field according to requirements, that is, either to broaden or to reduce the top of the block which in a block diagram would represent an assumed datum plane in the problem to be illustrated. From this upper surface all elevations and depressions are to be raised or lowered according to the to-

pography of the area to be pictured. This datum plane will represent an assumed elevation above which the hills or mountains must be raised (according to their elevation) and the valleys and canyons lowered, both in accordance with the scale adopted for the drawing. In most perspective drawing, a "plan" of the object to be shown in perspective is made first and the plan is projected into the picture plane (*PP*) in accordance with definite rules of perspective drawing. In preparing a block as described herein, the plan is omitted and the drawing is constructed by reference to specifications giving (1) the dimensions of the block and the distance of its near corner from the center (*C*) if desirable; (2) the distance from the observer; (3) the elevation of the observer; and (4) the scale of the drawing.

Since the position, size, and proportions of a block to be represented on the paper can be determined only by the perspective lines, some small trial sketches are usually made before the general shape or expression desired in the block is obtained. This is done by changing the elevation and distance of the spectator according to the subject and effect desired, thereby raising or lowering the horizon line and moving the vanishing points in or out until a block of satisfactory shape is outlined. The small drawing can then be enlarged and, if desired, put in true perspective to any desired size or scale.

A perspective drawing of a block can be made like that in Figure 17 in the following manner: First, construct a scale by which the different parts shall be kept in proportion to those of the object itself. In such a drawing the eye of the spectator will be sixteen feet (or units) above the ground and his position will be thirty feet (or units) distant from the object. Draw a line representing the horizon at the top of the sheet. Place the center of vision (*C*) on the horizon line in the middle of the sheet and draw a line downward perpendicular to the horizon. Point off sixteen feet, according to scale, on this line to represent the elevation of the observer and draw at that point another horizontal line parallel to the horizon line, extending it across the paper. This line will be the ground line of the picture plane. Check on this ground line twenty-four divisions on each side of the

center line to indicate the measurements of the sides of the block, and then point off thirty units on each side of C on the horizon line. These latter two points then become vanishing points VP^L and VP^R, respectively, or the limiting rays of the picture. The perpendicular line (C) having been extended downward, a point (S for station) also measuring thirty units below the horizon is then indicated. From these three points, VP^L, VP^R, and S, connecting lines, are run. It will be found that an angle of 90° thus produced at the station point (S) is subtended by 90 degrees on the horizon. When the corner of the block touches the center of the picture the angles at S will be 45° on each side of the perpendicular. When the block is shifted to one side (as in Figures 17 and 18) the angle it takes with the picture plane becomes 40° and 50°. It is generally best to show more on one side than on the other.

In the framework of such a diagram there are yet two more points to be located. These are the measuring points (MP^1 and MP^2), and they are found by describing an arc from VP^L to S and one from VP^R to S; at the intersection of these arcs with the horizon the two points of measure will be indicated. The use of these points, it is believed, is fully shown in Figure 17 and succeeding figures. Attention is called, however, to the fact that without these measuring points the correct limit of the block backward toward the vanishing points could not be determined in the diagram, since they are used to foreshorten horizontal distances. The block is 24 units square, and by pointing off that number of units on each side of the ground line (PP) from the corner of the block, and running lines from each division to MP^1 and MP^2, the intersection of those lines with the lower vanishing line of the block will give the true foreshortening of the block in perspective. From these points perpendiculars are raised and the lines continued to the vanishing points. Other parts of the problem of laying off a block in two-point perspective are visually explained in the diagrams.

In making a block diagram from a contour or other map, after the block has been outlined satisfactorily and to proper size and scale the map to be copied should be laid off with pen-

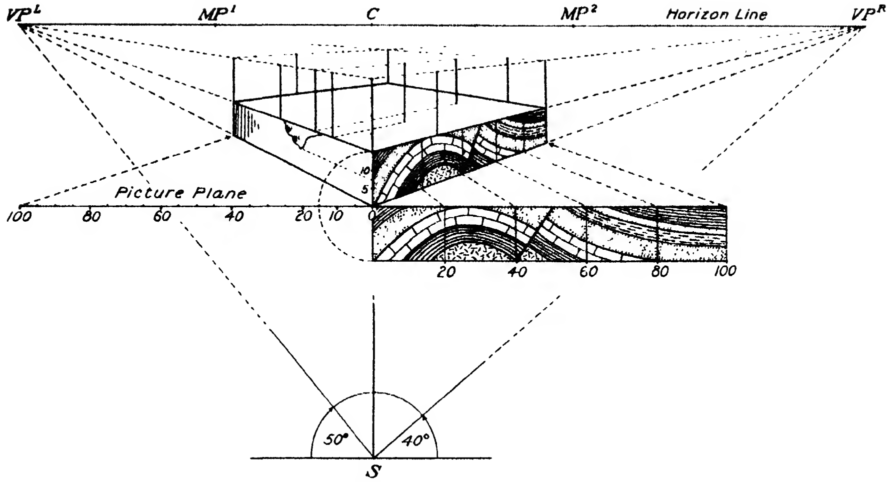


FIG. 18.—Diagram showing a method of projecting a section into the side of a block, and the indication of elevations and depressions.

ciled squares of any desired size. Sometimes advantage can be taken of the projection lines, or the land lines of the map. These squares are then projected upon the upper surface of the block. A method by which this can be done accurately is also shown in Figure 17. It will be noted that the squares gradually diminish in size in exact ratio to their distance from the eye, as they would appear to do in nature.

The same procedure is followed in projecting a section into the side of the block, as demonstrated in Figure 18. Figure 19 shows a block drawn in one-point or parallel perspective. All construction lines are of course omitted on the finished drawing.

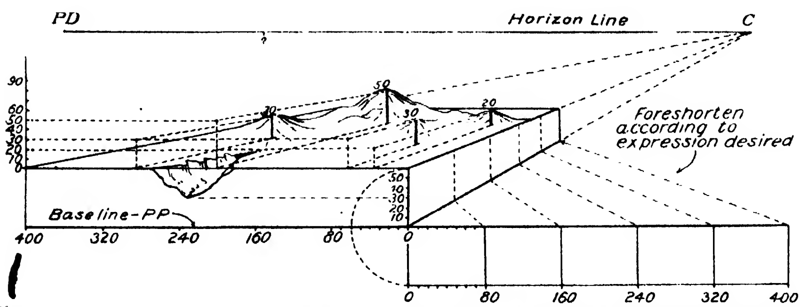


FIG. 19.—A block drawn in one-point or parallel perspective showing a method of plotting elevations and depressions.

After plotting a map, square by square, on the face of a block which has been laid off in squares proportionate with those of the map to be copied, all details will be found to have diminished also in the same ratio as the squares on the finished block, although the shape and effect of such detail will be radically different in appearance.

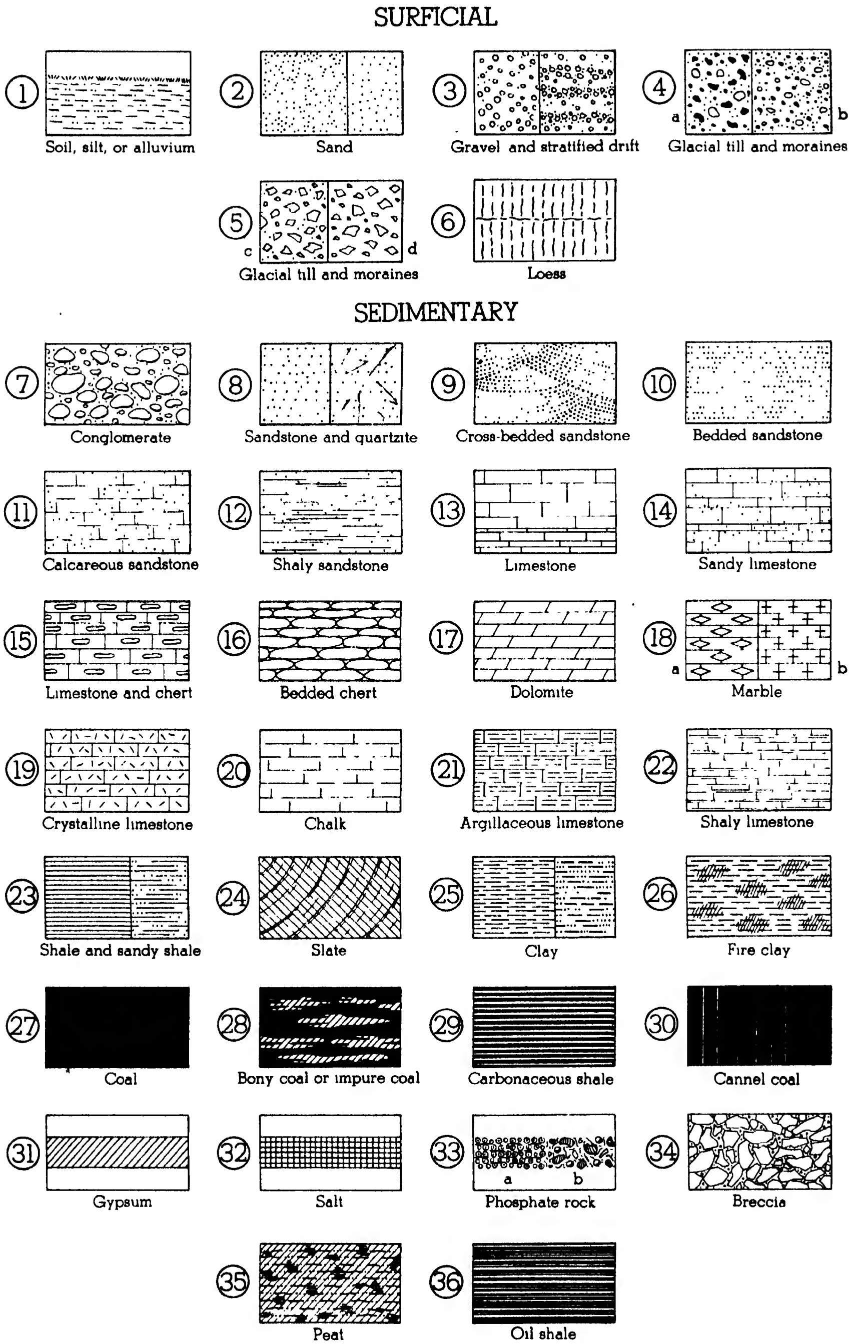
Figures 18 and 19 both offer a method of showing elevations and depressions on a block in true perspective. It is believed the two illustrations will give visual explanation to the method, which to some extent is complicated. In Figure 19 the scale has been placed on the side of the picture plane, from which all elevations must decrease toward the one vanishing point. In these figures the bases of the heavy uprights represent the location of the peaks, plotted from an accompanying map.

In Figure 18 the scale has been placed vertically through the front corner of the block touching the base of the picture plane, upon which all measurements must be taken and all measurements recede both ways toward the horizon. The heavy standards represent their varying heights according to their distance from the front of the block, measured from the datum plane.

§47. Structure Sections

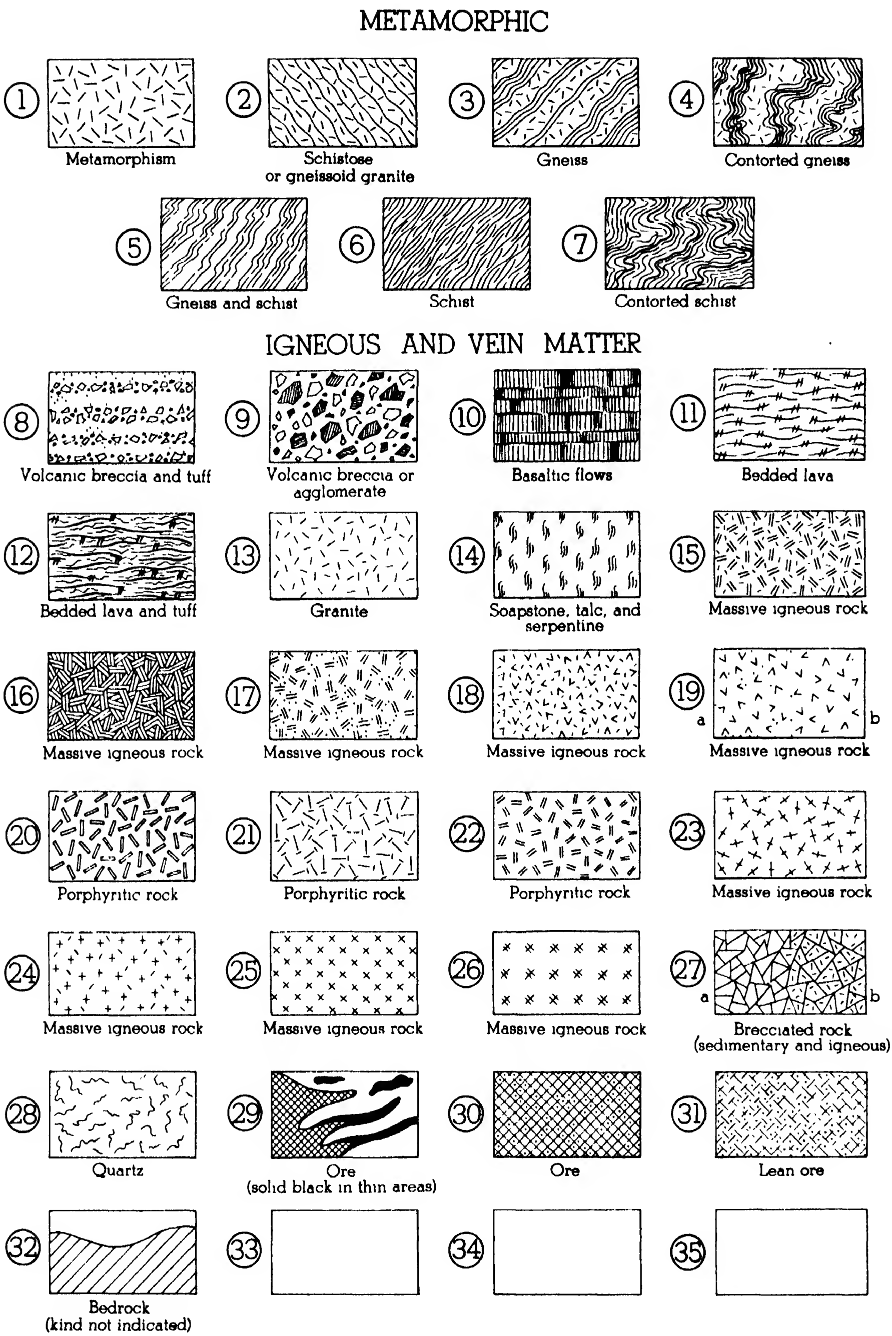
Author's preparation.—Since a finished drawing of a section can be prepared only from sketches and notes made in the field, it is important that the field drawing be made to show all necessary detail, avoiding any special attempt at refinement of technique. Any field drawing of a section along a definite line or zone that is not indicated by a similar line on an accompanying map should be so prepared that its details can be followed without question. On the other hand, in redrawing a section that represents the structure along a given line or zone on a geological map, the outcrops may be made, finally, to coincide with the topography and the formation boundaries; but the author's interpretation of the structure should be plainly indicated by him before it reaches the draftsman. All essential facts relating to bedding, folding, faulting, crosscutting dikes and veins, or other

PLATE XX



Lithologic symbols

PLATE XXI



Lithologic symbols (*continued*)

significant details should be shown in such a way that the essential facts will be clearly expressed.

Field sections should be drawn to a stated vertical and horizontal scale, and if differentiated the two scales should be shown on the drawing. The vertical exaggeration creates distortion, and its effect is misleading. It is recommended that structure sections be drawn on ruled paper prepared especially for that purpose; this may be obtained at a stationer's.

Final preparation.—Sections are of two widely different kinds. One shows only the broader relations of parts; the other shows details of structure as well as the broader relations. One is diagrammatic; the other is more realistic. New drawings should be prepared strictly according to the copy supplied by an author, but lithologic character should be expressed by adopting the standard conventional symbols shown in Plates XX and XXI.

Structure sections can be prepared so as to give a satisfactory expression of nature. The draftsman should study well-prepared sections and should examine the details of folding and faulting from textbooks. He should first ascertain whether or not the vertical scale in the original section has been unduly exaggerated or if there are points of doubtful interpretation. A seeming inaccuracy in an author's drawing may be a faithful representation of natural conditions (see Figure 20).

When a section shows irregular folding, penciled lines indicating the supposed continuance of formation boundaries beyond the section should be carefully added; after the drawing

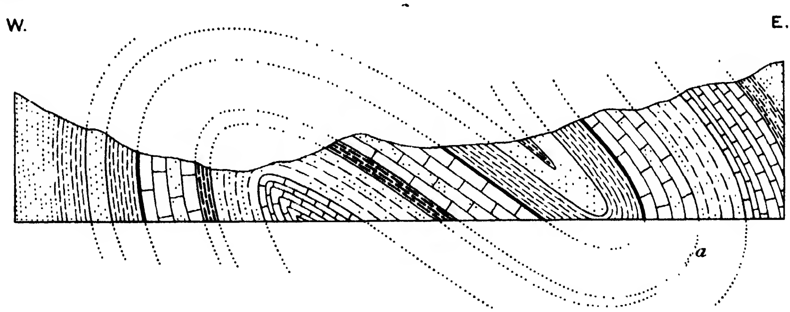


FIG. 20.—Structure section showing method of determining the succession of folds, and the pinching out of one formation at *a*.

FIG. 21.—Section and view showing relation of surface features to the underground structure.

is finished they can be erased. An original indefinite field sketch that shows complicated structure affords many opportunities for error in preparing the new drawing, and omissions can always be detected by following the formations as they would be continued above and below the section. These same general principles apply to other kinds of sections.

A cross section not often used, but which gives a more pictorial and clearer conception of surface and structural relations than the plain section, is made by adding a simple sketch of the topography, if known, above the section, thus converting the figure into a simple block diagram, as shown in Figure 21.

§48. Columnar Sections

Author's preparation.—An author's original drawings representing columnar sections, or sections in wells or ravines, should bear indication of all well-defined or important mineral deposits. If the deposit contained unusual features or details,

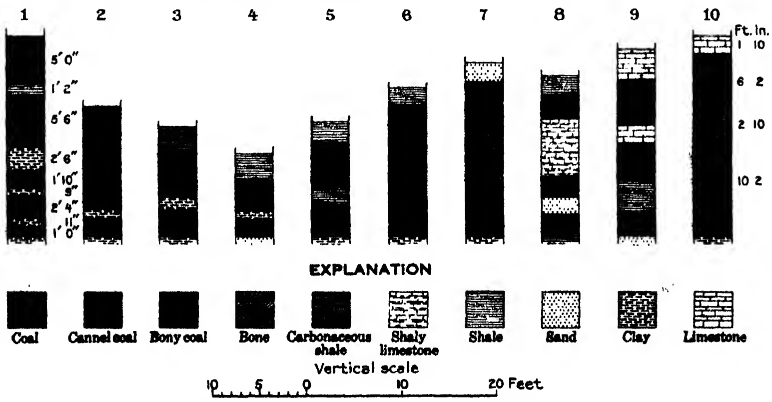


FIG. 22.—Sections of coal beds, showing publication size and the arrangement of the sections.

they should be identified by names such as "ashes and charcoal," "artifacts," "fossils," etc., and the important occurrences definitely indicated. The sections should, however, be so plotted and subdivided that each section will be complete in itself. The combinations of various parts into a single unit by a draftsman, or the making of such a drawing by reference to tables alone, is difficult and often leads to error.

Coal sections.—Coal sections designed to show the relative thickness of beds, and arranged in groups for publication, should be drawn in columns four-tenths of an inch wide and reduced one-half. Whether correlated or not, they should be drawn to some definite vertical scale and should show the thickness of the coal, preferably by numbers indicating feet and inches, the other material being symbolized and the symbols explained graphically. The vertical scale should always be stated. A bar scale by which the depth or thickness of each bed may be measured may be used instead of figures. Sections of this type can be prepared from tabular data (see Figure 22).

§49. Plans of Mine Workings

Kinds of copy.—The most acceptable copy from which to prepare plans of mines or underground workings consists of blueprints obtained from mining companies. In such copy all unnecessary or irrelevant details must be canceled, and every essential feature, especially any added data, must be clearly indicated. Many such blueprints are large and unwieldy and have to be greatly reduced before a new drawing can be prepared. If the lines are too weak to photograph, a tracing of the essential parts can be made and reduced to about twice publication size. The shadowless drafting table, described in §41, is well adapted to the work of making such tracings, in which only the parts desired may be traced. Blueprints can also be pantographed to any convenient size if the details are not too minute or complex.

Final preparation.—In finished drawings showing mine plans the various levels and underground workings can be differentiated by a system of conventional outlines in black, as

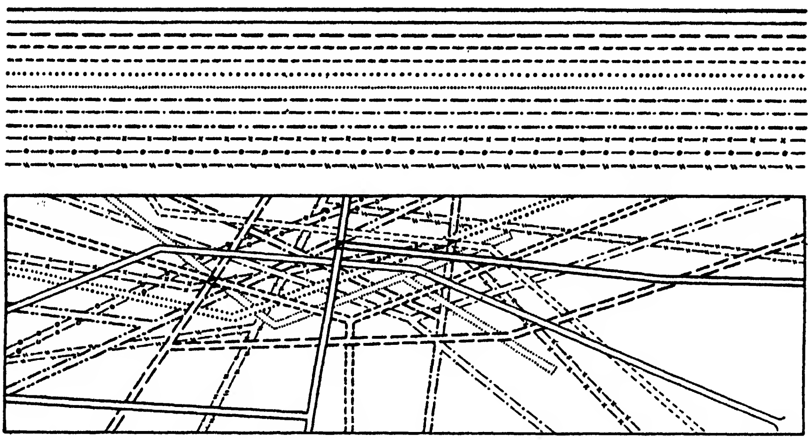


FIG. 23.—Conventional lines used in preparing plans of underground workings at different levels.

shown in Figure 23, or they may be shown by conventional patterns or symbols within plain outlines or by colors. Such plans should be printed in colors only where the maze of workings is so complicated that the conventional outlines would become confused if printed all in black. It will be seen in Figure 23 that the thirteen levels are readily distinguishable in black. Some plans require different styles of lettering, especially geographic or other names that should be in agreement with those on maps or other illustrations in the book. Unless there are good reasons, however, for varying the styles of lettering, plain hairline Gothic capitals, or capitals and lower case, either upright or slanting, should be used. Abbreviations for the numbers of levels are generally given thus: "3d level," "6th level," "200-foot level." The same general scheme of lettering should be used on all plans and cross sections that are to appear in one publication or in one series of similar papers. The reduction of such drawings to the minimum scale consistent with clearness is always advisable.

§50. Lithologic Symbols

General directions.—The standard symbols used to indicate the various kinds of rocks in sections and diagrams are shown in Plates XX and XXI. It should be well understood that the

units or elements of these symbols are spaced more openly in generalized or diagrammatic sections than in sections that show great detail, and they should be used consistently throughout a report. In order to make the symbols consistent in any one set of illustrations a symbol to be used for each kind of rock should be selected before the drawings are made. Some inconsistencies may be unavoidable on account of the small size of some areas and the contrast needed between others; but any deviation from the set of symbols adopted should be minimized.

§51. Revision of Illustrations

Before engraving.—Every drawing should be carefully checked before it is sent to the engraver: first, with reference to the correctness of scientific names and statements, and then with reference to errors in lettering and spelling. Each illustration should thus receive critical examination by persons qualified to give expert attention to a particular kind of work.

Too much attention cannot be given to a careful scrutiny of all lettering prepared by hand. A letterer is often so absorbed in the formation and spacing of each letter that an intelligent appreciation of what he is doing is momentarily sidetracked. Hence the omission of letters, occasional misspelling, and the interchanging of a word may result.

§52. Submittal of Proofs

It is customary to submit first proofs of all illustrations to an author for criticism when he is within reach, and his criticism should include any comments on the general effectiveness of each proof. Second proofs of the more complicated illustrations, particularly maps and other illustrations printed in colors, may not be submitted, since it is generally understood that approval is given to such proofs conditionally.

§53. Proofreading Illustrations

Completed copy for illustrations should be read with the utmost care before negatives are made; and the first proofs of each copy should likewise be examined carefully. Changes cannot be made in line cuts except by eliminating parts, cutting

away defects, and connecting lines. If additions are required, re-engraving is generally necessary, and re-engraving should be avoided.

A slight improvement can sometimes be made in half-tone plates by re-etching or by tooling parts to make them lighter and by burnishing parts to make them darker. When a proof of such a plate shows a general loss of detail it may have been caused by faulty proving of the cut, in which case new proofs should be requested; if it is in the reproduction it cannot be remedied without re-engraving. A slight loss of detail may be expected in all half-tones, especially in those that are smaller than the copy submitted. Proofs of 3-color and 4-color half-tones, whether progressive or complete, are submitted only once, and are returned subject to the corrections indicated thereon.

Only minor changes can be made in photolithographs and chromolithographs, and changes cannot be made twice in one place without danger of affecting the printing. It is therefore customary to approve all lithographic proofs subject to the corrections indicated on first proofs, the printed edition being subject to examination for proof of changes and approval. Second combined proofs of all colored illustrations are very expensive.

Proofs of illustrations reproduced by photogravure and the photogelatin processes require careful checking. Any extensive change in such proof sheets in general cannot be made without "making over" the plates; but slight changes can be indicated on first proofs, subject to approval in the edition. Any needed changes or corrections in the lettering, which in these processes represents a separate printing, can be made without difficulty.

A mere cursory examination of proofs may fail to reveal errors that have not been caught by the regular proofreader. As stated, examination should be confined principally to the revision of scientific features, but suggestions as to general effectiveness are always acceptable. Every correction desired should be clearly indicated with a soft pencil on the proof and inclosed in a loop from which a line should be carried to the margin for note or comment. In correcting type matter or lettering, the ordinary proofreader's marks should be used.

Since a time limit is often imposed upon the engraver, proofs should be held only long enough for examining them properly and comparing them with the original illustrations. If proofs are held beyond a reasonable time, delay in the fulfillment of the contract results.

§54. Borrowed and Fragile Specimens

Specimens borrowed for the purpose of making illustrations from them and those that are fragile should be marked in such a way that the engraver will be warned to take especial care in handling them. It is customary to return specimens borrowed from other institutions or from individuals just as promptly as possible.

§55. Copyrighted Photographs

Section 4965 (chap. 3, title 60) of the *Revised Statutes,* amended by act of March 2, 1895 (*Stat. L.,* vol. 28, p. 965), provides that no copyrighted photograph may be used without the consent of the proprietor of the copyright in writing signed in the presence of two witnesses. A penalty of $1.00 is imposed for every sheet on which such a photograph is reproduced without consent, "either printing, printed, copied, published, imported, or exposed for sale." It is therefore important that the written consent of the owner of a copyrighted photograph be obtained before using it, and that the letter giving this consent be submitted with illustrations and manuscript. Credit is frequently indicated by the symbol © with the owner's name in small letters in the lower margin.

§56. Credit for Re-use of Published Illustrations

In making a request to use an illustration already published in book form, one need quote only the title of the volume in which it was used, along with the number of the page, figure, or plate. If, however, the illustration accompanies a separate article in a series of papers, its author's name should also be mentioned. It is not necessary to make a sketch of the illustration or furnish a dummy, but the title of the illustration desired should be

quoted. It is, of course, customary to give due credit to both author and publisher, and most copyright owners require such credit when permission to use is granted.

§57. General Considerations

The following requirements are essential in obtaining good original illustrations:

1. The material selected in the first place should be pertinent and expressive; it should have the qualities essential to the making of good illustrations.

2. The kind of publication and the size of the illustrations should be kept clearly in mind. If the report is to be only preliminary or ephemeral, the illustrations should be simple and inexpensive. If the report represents the sum of knowledge on the subject treated or purports to be the last word on some particular problem or region, the illustrations should be more elaborate. The character of a report generally determines the form of publication, which, in turn, determines the size of the page and the size of the plates and figures. It is generally essential that every sketch made should be larger than publication size, preferably twice publication size, whether it is a simple diagram or a base map.

3. The kind of reproduction—line cut, half-tone, lithograph, etc.—that would apparently be needed should be fully considered, for it should have some relation to the kind of report. The illustrations for short-lived reports are reproduced by the cheaper processes; those for hurried reports by processes that can be worked quickly. But no process should be considered that will not give a clear reproduction of essential details.

4. Above all, clearness of preparation of original matter is always essential. An author who has his drawings made should not expect the draftsmen or the editors to supply missing links. Each original should be complete and should be so made that it can be understood and followed without question. Unnecessary changes should be avoided both in the finished drawings and in marking proof sheets; they are expensive and delay publication with no apparent gain.

§58. Processes of Reproducing Illustrations

Essential features.—The work of preparing illustrations is essentially that of making finished drawings from more or less crude and imperfect material furnished by authors, preparing photographs and other material, and reproducing each by one of the engraving processes. Each of the finished drawings must be so prepared that it can be reproduced by one of several processes of engraving and be printed in multiple. The author's sketches and other material are commonly called "originals"; the finished drawings are known by the engravers as "copy." Though most engraver's copy includes more or less elaborate drawings that are to be reproduced in facsimile by what are called "direct" processes, that is, without handwork, some of it consists of more roughly prepared copy which is accurate in statement but requires complete manual or "indirect" reproduction. The direct processes in use are zinc etching, half-tone engraving, multicolor half-tone engraving, photolithography, photogravure, and the photogelatin process. The manual or indirect processes are wax engraving, wood engraving, engraving on copper and on stone, plain lithography, and chromolithography.

Each of the several processes commonly used for preparing plates for printing illustrations has its own peculiar features of excellence. One process may render fine details but lack uniformity in large editions; another may be cheap and effective on the whole but not reproduce fine details with entire satisfaction; and still another may give fine color or tone effects but be too expensive. Therefore a knowledge of the varied results to be obtained and of the comparative cost of the several processes of reproduction and, on the other hand, of the kinds of originals that are best suited for reproduction by each of the processes is essential to effectiveness and economy in planning, preparing, and reproducing illustrations.

The following condensed descriptions of processes are intended to aid in determining the kind of drawing or "copy" that will be appropriate for each of the processes in general use and

the kind and quality of reproduction to be expected. The descriptions cover only the principal or fundamental operations in each process. Wood engraving, which was formerly much used in making printing plates for illustrations, is described here in some detail only to compare that laborious and "indirect" method of engraving cuts with the more modern kinds of relief engraving.

Photoengraving.—Photoengraving is a general term applied to processes by which a drawing consisting of black lines, dots or masses of black, or a photograph or some similar original is reproduced in relief on a metal plate from which prints may be made on an ordinary printing press, in distinction to processes that print from flat or relatively flat surfaces, such as the lithographic, photogravure, and photogelatin processes. The photoengraving processes that are most commonly used are those called "zinc etching" and "half-tone engraving." These processes depend on the discovery that gelatin or similar organic material, if treated with potassium or ammonium bichromate and exposed to the action of light, is made insoluble in water. If a metal plate coated with bichromatized gelatin or albumen is exposed to light under a negative, the parts acted upon by light become insoluble and those not acted upon remain unchanged and may be washed away so as to expose the metal, which is then etched with acid in order to give relief to the exposed parts and make of them a printing surface.

Zinc etching (line cuts).—A drawing prepared with pen and black ink and composed of lines, dots, or solid black areas is usually marked for zinc etching—or, to use a common term, "line cut." On the finished metal plate these lines, dots, and solid areas form the printing surface, and the spaces between them, which have been etched away, represent the white or blank parts of the picture. The process is cheap and is almost universally used for reproducing small drawings designed for text illustrations. One of the chief advantages of this and of all other "direct" (photographic) processes of engraving is that they reproduce a drawing in facsimile, whereas the "personal element" must enter into all engravings made by an "indirect" method—

that is, by hand—such as wax engraving, wood engraving, and engraving on stone or copper, which make it necessary for an author to compare every detail of the proof with the drawing before approving the engraving. The pen drawing to be reproduced by zinc etching, which should be larger than the completed engraving, is first photographed to the proper size or scale on an ordinary negative. The film is then stripped from the negative and reversed, in order that the etched plate may print the design as in the original and the film may be grouped with others on one large glass and all printed at the same time. The negative (whether a single film or several) is then placed in a specially constructed printing frame in contact under pressure with a sensitized zinc plate and exposed to light.

After the zinc plate has been removed from the printing frame, it is rolled with printer's transfer ink, which resists acid, and is placed in a shallow tray containing water; here it is rocked for several minutes and then taken out and rubbed gently with cotton. The parts of the coating of the plate that were acted on by light (the lines of the drawing) have become hardened and insoluble and will therefore be unaffected by the water; but the parts of the coating not acted on by light and therefore not hardened will be removed by the washing, thus exposing the metal and leaving the parts acted on by light—the picture—in black lines, dots, etc. The plate is then etched with a weak solution of nitric acid, and after several minor operations the etching is repeated until it is etched deep enough to insure satisfactory printing. It is then ready for finishing, which consists of deepening the larger open spaces between the lines with a routing machine and cutting away with hand-gravers lines that are improperly connected. An impression is then taken from the plate and, if satisfactory, the plate is nailed to a block of wood on which it must be "type high" (0.918 inch), ready for printing. Line cuts are also furnished on metal bases instead of wood.

As stated, drawings for zinc etching are made with pen and black ink. Shades may be added by using some medium that will produce fine lines or a fine stipple. Ben Day patterns and tints can also be used by the engraver to differentiate areas, if

required. Every drawing should be one and one-half times or, preferably, twice the linear dimensions of the printed illustration. If the drawing has not been reduced, the lines generally appear heavier in the reproduction than in the drawing, and imperfections thus become more noticeable; if it has been properly reduced, imperfections are diminished. The larger drawing also offers greater freedom in drawing details.

Finished drawings for this process should be carefully examined and approved before they are engraved. Corrections cannot be made in the cuts except by expensive handwork.

The cost of zinc etchings is varied according to a standard scale which is based upon the ascertained cost of reproduction. The minimum charge for a single cut ready for printing is now (1937) $3.12, by the scale of the American Photo-Engravers' Association. If a copy calls for a silhouette cut, the routing or cutting away around the figures adds about 30 per cent to its cost.

Copper etching of line cuts.—Copper etching, which produces a line cut in relief, requires the same kind of copy that is most often marked for zinc etching and is used to obtain finer etching and a more permanent cut. It is said to produce better printing plates than those etched on zinc for reproducing script lettering and other very fine work. Line cuts etched on copper cost, according to standard scale, about twice as much as those etched on zinc.

Half-tone engraving.—The invention of a photomechanical process of reproducing a shaded drawing so as to make a metal relief plate that can be printed along with type similar to a line cut naturally led to attempts to reproduce a photograph. It was known that the intermediate shades between white and black in a photograph—the half-tones—could be reproduced on an ordinary printing press only by breaking them up into dots or lines that would form a good printing surface; and that by their variations in size or density these dots or lines would give for each shade the effect of a uniform tone. In the half-tone process this effect is produced by photographing the picture or object through a screen. The process is, in name at least, familiar to almost

PLATE XXII

175-Line Screen

150-Line Screen

133-Line Screen

120-Line Screen

100-Line Screen

60-Line Screen

Half-tone cuts showing effect of six standard screens reproducing same detail

everyone who has had any connection with the making of books, whether as author, editor, illustrator, or printer.

The half-tone screen consists of two plates of glass, on each of which lines running (generally) at an angle of 45° to the sides of the plate have been engraved, the plates then being cemented together so that the lines cross at right angles. The lines, which are minute grooves filled with an opaque black pigment, thus appear as a series of minute black crossed lines on a white ground. Screens are made that show from 60 lines to an inch for the coarser newspaper illustrations to 250 lines or more to the inch for fine book work. The screens used for magazine illustrations generally show 120 to 150 lines. Those used for reproducing delicate drawings and photographs of scientific specimens show 150 to 200 lines to the inch; but these finer screens require the use of highly supercoated papers for printing. For a half-tone that is to be printed in the text, a 120-line or a 133-line screen is often used. Plate XXII shows the effect of six different standard screens used in the reproduction of the same detail.

There are several kinds of half-tone plates, including those etched on copper and on zinc, of which the latter are used principally for newspaper illustrations. The half-tone screen is used also in other processes to obtain a negative from which a screen effect can be superimposed upon certain parts of an engraving.

The etching fluid for half-tone plates on copper consists of a saturated solution of perchloride of iron, instead of the solution of nitric acid used for zinc etching. If the sky in a half-tone plate shows too dark or is uneven in tone, it can be made lighter or more even by re-etching. On the other hand, if certain features on a plate are too light, they can be darkened by burnishing—rubbing the surface with a highly polished steel burnisher under pressure just sufficient to slightly flatten the fine points that form the printing surface of the plate.

The half-tone process is used almost exclusively for reproducing photographs and wash drawings, though it will produce a facsimile of any kind of copy, such as impressions from type (see Plate XIII), old manuscripts, typewriting, etc.; but a shade

composed of minute black dots will appear over the entire print and there will be no absolutely white areas unless they are produced by "routing" or cutting out the surface at those points, or by "highlight" etching—an expensive procedure not usually adapted to scientific illustration. The reproduction of an ordinary outdoor photograph requires very little additional hand work; but in copy that is made up of separate parts, such as groups of photographs or specimens that are to appear on a white ground, the half-tone "tint"—or, more properly, shade—between and around the several figures must be removed and numbers must be added. Such copy should be marked for a "silhouette cut." Adding numbers may require two negatives—one half-tone and one line— and produces what is called a "combination" plate. Therefore the cost of making a half-tone cut from a single photograph is considerably less than that of making one from "copy" of the same size consisting of a number of small photographs or drawings to which numbers or letters are added. (See Plate VII.)

The half-tone process being direct and photographic, all copy should be as nearly perfect as possible. Only good photographs or those expertly retouched should be used. Prints on Velox, Azo, and glossy haloid papers are regarded as the best photographic copy for reproduction. Every part of the photograph or drawing should be absolutely clean. If any part becomes soiled or stained, its defects will be reproduced. If a photograph needs retouching, this should be done with great care and just sufficiently to correct defects and to bring out or strengthen the important details (see §§20, 21).

Line drawings are not generally suitable copy for the half-tone process, but such drawings can be so reproduced. In reproducing a pen drawing by half-tone, any needed improvement of the drawing by shading can be made with a brush before it is engraved. Examples of this type of reproduction are Plates *V^A*, *VI^A*, XV, Figure 10, and other illustrations in United States Geological Survey *Monograph XXXIV*. Vignetting, as well as extensive tooling or hand engraving, is sometimes employed for artistic effect but is used only for exceptional illustrations.

The cost of a half-tone cut etched on copper is varied according to size and a standard scale based on the ascertained cost of reproduction. Those that require a screen finer than 150 lines cost 25 per cent additional. The minimum charge for a single cut is $4.27, by the scale of the American Photo-Engravers' Association.

Half-tones etched on zinc (100-line screen or coarser) cost about 25 per cent less than those etched on copper. They are not appropriate for fine book illustration.

Three-color half-tone process.—The three-color half-tone process is based on the theory that all colors or hues in nature can be reproduced by combinations of three colors of the spectrum—red, blue, and yellow. The process differs from the ordinary half-tone process particularly in the use of color filters in making the negatives and in the character of screens and diaphragms used. This process, like all others, is worked somewhat differently in different establishments. In what is called the "indirect" method (the one most commonly used), twelve photographic operations are necessary to produce one illustration or the three plates or cuts from which one illustration is to be reproduced by printing. These twelve operations produce three chromatic negatives, each representing one color; three transparencies or positives; three half-tone negatives made from the positives; and, finally, three contact prints made on sensitized metal plates.

Unfortunately, no pigments have been found that have the brilliancy and purity of the spectrum colors, and to this fact is due the failure of the process to reproduce with absolute exactness all the colors, tints, and shades of an original. When a drawing in black on white paper is photographed, only the white paper affects the negative film. The transparent parts of the developed negative thus represent the black, and the opaque parts, which have been acted upon by light, represent the white. Theoretically, when a chromatic negative is made for the yellow plate, a purple-violet filter cuts out all the yellow and allows the red and blue rays to affect the plate; when a negative is made for the blue plate an orange filter similarly cuts out the blue and

allows the yellow and red rays to affect the plate; and when a negative is made for the red plate a green filter cuts out the red and permits the blue and yellow rays to affect the plate. When printing plates have been made from each of the three negatives and the plates have been inked with bright clear yellow, peacock or Prussian blue, and bright crimson red, respectively, a combined impression from them will produce a close approximation to the subject photographed.

The ordinary half-tone screen, which bears lines cut at an angle of 45° to the sides of the plate, is rectangular; but the screens used for three-color work are made circular in order that they may be turned in the camera to make the lines intersect at other angles, the angles being varied to avoid producing an undesirable pattern or "moiré" effect.

As special experience is needed in printing three-color plates, it is customary for the engraver to deliver to the purchaser the printed illustrations instead of the plates, as he does for other kinds of relief printing, although more recently multicolor plates mounted on a metal base are furnished a publisher equipped for doing his own color printing.

Copy for the three-color process may consist of anything in color, such as drawings of specimens, colored objects, paintings, or colored photographic copy. While the process cannot reproduce all the colors and tints of an original with absolute exactness, it is satisfactory for reproducing most colored drawings, colored photographs, or the specimens themselves if they show individual variations in color. As the process is entirely photomechanical, it gives more scientific accuracy in detail than chromolithography, in which there is much handwork; and it is less expensive. If the colors shown in proofs are not satisfactory, they can be modified.

The same process, sometimes known as the multicolor process, in which four color plates are used, gives a closer approximation of true color values than the three-color process, and at a comparatively small increase in cost. The additional color used is generally a neutral gray. The frontispiece in this volume is an example of this kind of reproduction.

Estimates for such work can be obtained from engraving companies only after they have examined the copy.

Wax engraving (the cerotype process).—It is always well for an author to keep in mind the fact that his rough drawings, prints, or any kind of original material in which lines, dots, and lettering are to be shown can be engraved by the wax process.

This process does not require finished drawings and is especially suitable for making text illustrations and small maps, although it may be used also for larger work. The wax engraver will reproduce in proper form any illustration in which the copy and the instructions show what is wanted, just as an experienced draftsman will make a good drawing from the rough original furnished by an author. Full and clear instructions should always be given, however, as to the size of the cut wanted and what it is to show.

In this process a polished copper plate is coated with sensitized film consisting of beeswax and other ingredients. The coating varies in thickness according to the nature of the copy. The map or other design to be engraved is photographed to publication size and a contact print is made on the wax coating from the negative. The lines and other parts of the photographed image are then traced or cut through the wax to the copper plate with steel tools and straightened and otherwise perfected by the engraver; but the lettering is set in type, which is pressed into the wax until it also touches the metal plate. After the work of tracing through the wax has been completed, the larger spaces between the lines are "built up" by the addition of wax to give greater depth to the plate, so that the wax plate thus built up corresponds to an electrotype mold. The plate is then dusted with powdered graphite and suspended in a solution containing copper, where by electro-deposition a copper shell is formed over its surface. When this shell is sufficiently thick it is removed from the solution and reinforced with metal. Proofs are then taken from it, and if satisfactory the plate is made ready for printing.

Wax-engraved plates may also be used for printing colored maps or diagrams in which variations of tint are produced by

various kinds of machine rulings. The effect of some of the rulings thus produced is almost a "flat" tint. Some color work is also printed from a wax-base plate in combination with half-tone color plates.

The price of a wax engraving depends entirely on the size of the cut, the amount of work involved, and the character of the original copy, but it should not greatly exceed the cost of a carefully prepared pen drawing plus the cost of a zinc etching made from it. Cuts engraved by the wax process, like zinc and half-tone plates, are delivered to the purchaser. A wax engraving gives sharp lines and more uniform lettering than a zinc etching, unless the hand lettering has been very carefully prepared and properly reduced.

Wood engraving.—Wood engraving, while now but little used, was once the universal method of producing cuts designed to be printed on an ordinary press. It is said to be the oldest of all methods of engraving illustrations. The engraving is made on a block of boxwood, a very dense, hard wood of a light yellow color. The block is cut type-high, across the grain, and the engraving surface is made absolutely smooth by rubbing it with pumice or other fine abrasive. When a cut is to be larger than 3 or 4 inches square, the wood block is made up of pieces securely dovetailed or joined together to prevent splitting and warping. A woodcut is not used for printing but is electrotyped and the electrotype is used in the press.

Originally the smoothed surface of the wood block was coated with prepared chalk or Chinese white, and on this coating a finished drawing was made with brush and pencil by an illustrator. According to later practice the surface of the wood is covered with a sensitized coating, on which the drawing or design to be engraved is photographed. The engraver then, with various kinds of gravers and other tools, cuts out the parts of the picture that are to be represented by white paper and leaves the lines, dots, and black areas as a printing surface, thus translating the shades and tints of the picture into a system of lines and dots which exactly duplicate in effect the details and tones of the original design. In order to produce a line effect of an

area in which the tone is intermediate between white and black, the engraver must space his lines so that one-half the area will remain as printing surface and the other half as white spaces, and he must give character and direction to his lines. Many wood engravers became noted for their artistic rendering of magazine illustrations, famous paintings, and other works of art.

This method of engraving began in 1884 to give way to the cheaper photomechanical processes.

Photogelatin processes.—Bichromatized gelatin is used in several photomechanical processes of reproducing illustrations, but in the photogelatin processes the gelatin not only receives the image by exposure to light through a negative but becomes a printing surface on a plate from which prints are made somewhat as in lithography. The several photogelatin processes are much the same as the original collotype process and are best known by the names collotype, heliotype, Albertype, Artotype, and the German name *Lichtdruck.*

In working these processes a thick plate of glass is coated with sensitized gelatin. The subject to be reproduced is then photographed in the usual manner, and unless a prism or mirror box has been used the negative is stripped and reversed in order to make the print reproduce the original in proper position. A contact print is then made on the gelatin-coated plate, the parts or molecules of gelatin being hardened in proportion to the amount of light that affects them. Before prints are made from the gelatin-coated plate, water is flowed over it and penetrates the different parts of the gelatin according to their hardness. The darkest parts of the picture will correspond to the hardest and densest parts of the gelatin, which will not absorb water; the lighter parts will take up some water. The ink, being greasy, has no affinity for water, and when it is rolled over the plate it adheres only to the dry parts of the gelatin and in the press is carried to the paper in all the lights and shades of the illustration. The paper used for printing from photogelatin plates must be free from chemicals that will affect the gelatin; a nearly pure rag paper is generally used.

The photogelatin process is well adapted to the reproduction

of very delicate drawings done either with pencil or in washes, photographs, photomicrographs, works of art, old manuscripts —in fact, any kind of subject in which the reproduction of all the delicate lights and shades is essential. If properly manipulated it has a distinct advantage over the half-tone process in that it can reproduce details and shading without showing a screen effect and without the use of coated paper for printing. Excellent reproductions by the heliotype process have also been made in color by first printing the design in a neutral tone and superposing appropriate transparent colors on this print, somewhat as in chromolithography, so that the colors softly blend with the shaded groundwork.

Reproductions made by the photogelatin process are delivered completely printed. They are more expensive than those made by the half-tone process, since the prints are made on better paper and are printed more slowly and with greater care. They are perhaps unrivaled by prints obtained by any other process except photogravure, in which the image is printed from a metal plate that has been sensitized, exposed under a reversed negative, and etched.

Changes cannot be made on photogelatin plates except by making over the corrected parts. All retouching must be done on the originals or on the negatives made from them.

Lithography (original process).—Lithography is a general term applied to all the processes that print from stone, including engraving on stone, as well as engraving on copper as a means of supplying matter to be transferred to and printed from stone. To describe lithography in its original form would be to give an outline of the process as it was discovered and invented by Senefelder. Senefelder discovered that limestone will absorb either grease or water, and that neither will penetrate a part of the surface previously affected by the other. He found that if a design is drawn on limestone with a greasy crayon and the stone is afterward properly prepared with a solution of nitric acid and gum, the greasy ink of a roller will adhere only to the parts that were covered with the crayon, and the stone will give off an impression of the design.

Lithographic stone is described as a fine, compact, homogeneous limestone, which may be either a pure carbonate of lime or dolomitic; that is, it may contain magnesium. Although limestone is one of the commonest rocks, limestone of a quality suitable for use in lithography is found in only a few localities.

In the original process two methods are employed in putting on stone the design to be reproduced. In one the subject or picture to be reproduced is drawn on the printing stone. In the other method the drawing is made on transfer paper and transferred to the stone.

Before a drawing is made on a stone, one of the quality suited to the particular design in hand is selected. The stone is then ground, and polished or "grained" according to the special requirements of the subject. This method of drawing on stone is used also for preparing color stones in the process of chromolithography, in which there are many added details of manipulation.

Lithographic prints from stones prepared in this way are made on a flat-bed press. The stone is carried forward to print and on its return dampened and inked, an operation slower than that of rotary printing.

This form of lithography, which covers the fundamentals of lithography, is seldom used now but was formerly much used and was well adapted to the reproduction of drawings of fossils, particularly of remains of dinosaurs and other types of large extinct animals, and to posters and commercial work, for which the drawings were made directly on stone.

A drawing or any kind of design, map or other subject, made on one stone may be transferred in duplicate or in any desired number to another stone or, in the more modern process, to a properly grained sheet of zinc or aluminum, from which impressions may be printed on a lithographic press. Both these metals are also used for lithographic printing on rotary presses, the zinc or aluminum plate being bent and secured around a cylinder which rotates continuously in one direction. As one impression is made at each revolution of the cylinder, the printing is more rapid than that done from the stone itself.

Photolithography.—Photolithography, like all other processes, has been improved greatly during the last few years by the introduction of metal plates, the rubber-blanket offset, and many other mechanical and chemical devices. Hence a brief description of it will explain the process only in a most general way. As photolithography is a direct process and is relatively cheap it is the one most used for reproducing large maps and other line drawings that have been carefully prepared. Zinc and aluminum plates are now generally used in photolithography, for a direct contact photographic print can be made on them, they can be printed flat or bent for use on a rotary press, and they can be stored for future use more economically than stones.

There are two somewhat distinct methods of producing photolithographs. In both the ordinary photographic methods are used. If the copy to be reproduced shows three colors, three negatives are made, and the parts to be shown by each color are preserved by "opaquing" or painting out all other parts. By the older method the negative thus perfected is printed on transfer paper, from which the design is transferred to the printing stone or metal plate.

The method now most used, which has been called the Planographic process, insures absolute scale and reproduces the finest line drawings perfectly without thickening the lines or without distortion.

A drawing that is to be reproduced by photolithography should be made on pure-white paper in lines, dots, or black masses with black waterproof ink. It should be one and one-half to two or three times the size of the finished print.

Photolithography is particularly adapted to the reproduction of maps, plans, and other large drawings. Within certain limitations, lines may be changed and details may be added after proofs have been submitted. The process is ordinarily used for reproducing illustrations in one color (black), but it is used also for printing in two or more colors, generally over a black outline base, each color being printed from a separate stone, as in chromolithography.

Offset printing.—In the offset process the design is "offset" from a lithographic plate to a rubber blanket on a cylinder, from which it is printed. By thus obtaining an impression from an elastic surface the finest details can be printed on fairly rough, uncoated paper, which cannot be used in other processes.

Chromolithography.—Chromolithography, one of the best known processes because of its early use in producing what were popularly known as "chromos," is used largely for reproducing geologic maps, paintings, posters, etc., but it has been used successfully for reproducing colored drawings of specimens. Good examples of this kind of reproduction will be found in United States Geological Survey *Monograph LII,* in which there are numerous reproductions of mineral subjects, and in the plates which accompany Bendire's *Life Histories of North American Birds.*

There are several other kinds of color printing from stones. One produces a picture by superimposing colors that combine and overlap without definite outlines and thus reproduce the softly blended colors of the original. Another reproduces the original by printing colors within definite outlines on a "base" which has been previously printed in black. The first kind is used for reproducing paintings and colored drawings of specimens. The second is followed in reproducing colored maps.

As each color must be printed from a separate stone and be properly fitted with respect to the others, a complete tracing from the original of the precise outlines of each color is made on specially prepared tracing paper or on a sheet of transparent gelatin or celluloid, which is laid over the copy and on which all the outlines and overlaps of the various colors are scratched with a steel point. The scratches thus made are filled with red chalk or like substance rubbed in with cotton. The tracing is then laid on the stone in reverse position. The chalk lines are deposited on as many stones as are needed to produce the colors of the original design—each stone bearing all the outlines of the complete design. The parts on each stone that are to have one color are then inked in or engraved, and at the same time guide marks are indicated so that the combined impressions will

show each color in its proper place. This fitting is called "register." In printing, each stone must be adjusted to a nicety while on the press in order to make its impression fit the others exactly. Photography has now replaced much handwork and has given rise to several methods by which the same kinds of subjects are reproduced in radically different ways.

In reproducing a geologic map the base may be engraved on stone or on copper, or, if a good pen drawing, it may be photolithographed. By either process the map may be transferred to the printing stone. In printing maps, pattern effects are engraved separately on stones, from which impressions are pulled and transferred to their proper places on the printing stones or plates. Often twelve or more colors and many distinctive patterns are used to produce a geologic map. When proofs of such a map are pulled, each stone must be taken up and carefully adjusted on the press. The work of proving such maps is laborious and expensive. It is therefore customary to approve first combined proofs conditionally, that is, subject to the corrections and changes indicated on the proofs.

This process is the most expensive one used for reproducing illustrations. Changes may be indicated on proofs, but changes cannot be made on a stone twice in the same place without danger of affecting the printing. Slight modification at one point may involve corresponding changes on a number of stones, each of which must be taken up, corrected, and proved in order to insure the exact coincidence of the parts affected.

Engraving on stone and on copper.—Engraving on stone is distinctly lithographic, but engraving on copper is sometimes included among lithographic processes because the work produced by it is often printed from stone or on metal plates as in lithography, and thus it becomes a lithographic process. In other respects engraving on copper is not lithographic. Roughly prepared maps and any rough line copy that is accurate in statement and clear as to intent are appropriate for both methods of engraving, while drawings that are expertly prepared are more suitable for reproduction by photolithography.

In engraving on stone the lines of a design are cautiously

scratched through the blackened surface of the stone with a steel needle. The points of some of the needles are fine; those of others are V-shaped; and some have spoon-shaped points for use in thickening lines and shading letters. All features are engraved in reverse.

In engraving on copper the lines are cut with a graver on a highly polished sheet or plate of copper, the matter to be engraved being first shown on the plate by what is called the phototracing process, which was devised in the United States Geological Survey. There is, however, no great or essential difference in the printed results of the two processes; but most lithographers employ only stone engravers.

In all lithographic processes the titles and other marginal lettering can be and usually are transferred from type impressions to the printing stones or to zinc and aluminum plates. It is therefore unnecessary to letter such matter carefully on an original drawing that is made for lithographic reproduction. Appropriate faces of type will give better printed results than hand lettering.

Corrections cannot be made on a stone or copper engraving as readily as on a drawing. If a stone engraver makes an error or if a change is required after his engraving is finished, the parts to be corrected must be scraped off and a new ground laid before the correction can be made. If corrections are made on copper plates the plates must be "hammered up" from beneath and a new surface polished off before the parts can be reengraved.

APPENDIX

TABLE I*

Lengths of Degrees of the Meridian

(The ratio of the yard to the meter as stated by Clarke, namely, 1 meter = 1.093623 yards = 39.370432 inches, is that used in the table.)

Latitude Degrees	Meters†	Statute Miles	Latitude Degrees	Meters†	Statute Miles
0	110,567.2	68.704	45	111,130.9	69.054
1	110,567.6	68.704	46	111,150.6	69.066
2	110,568.6	68.705	47	111,170.4	69.079
3	110,570.3	68.706	48	111,190.1	69.091
4	110,572.7	68.708	49	111,209.7	69.103
5	110,575.8	68.710	50	111,229.3	69.115
6	110,579.5	68.712	51	111,248.7	69.127
7	110,583.9	68.715	52	111,268.0	69.139
8	110,589.0	68.718	53	111,287.1	69.151
9	110,594.7	68.721	54	111,306.0	69.163
10	110,601.1	68.725	55	111,324.8	69.175
11	110,608.1	68.730	56	111,343.3	69.186
12	110,615.8	68.734	57	111,361.5	69.197
13	110,624.1	68.739	58	111,379.5	69.209
14	110,633.0	68.744	59	111,397.2	69.220
15	110,642.5	68.751	60	111,414.5	69.230
16	110,652.6	68.757	61	111,431.5	69.241
17	110,663.3	68.764	62	111,448.2	69.251
18	110,674.5	68.771	63	111,464.4	69.261
19	110,686.3	68.778	64	111,480.3	69.271
20	110,698.7	68.786	65	111,495.7	69.281
21	110,711.6	68.794	66	111,510.7	69.290
22	110,725.0	68.802	67	111,525.3	69.299
23	110,738.8	68.811	68	111,539.3	69.308
24	110,753.2	68.820	69	111,552.9	69.316
25	110,768.0	68.829	70	111,565.9	69.324
26	110,783.3	68.839	71	111,578.4	69.332
27	110,799.0	68.848	72	111,590.4	69.340
28	110,815.1	68.858	73	111,601.8	69.347
29	110,831.6	68.869	74	111,612.7	69.354
30	110,848.5	68.879	75	111,622.9	69.360
31	110,865.7	68.890	76	111,632.6	69.366
32	110,883.2	68.901	77	111,641.6	69.372
33	110,901.1	68.912	78	111,650.0	69.377
34	110,919.2	68.923	79	111,657.8	69.382
35	110,937.6	68.935	80	111,664.9	69.386
36	110,956.2	68.946	81	111,671.4	69.390
37	110,975.1	68.958	82	111,677.2	69.394
38	110,994.1	68.969	83	111,682.4	69.397
39	111,013.3	68.981	84	111,686.9	69.400
40	111,032.7	68.993	85	111,690.7	69.402
41	111,052.2	69.006	86	111,693.8	69.404
42	111,071.7	69.018	87	111,696.2	69.405
43	111,091.4	69.030	88	111,697.9	69.407
44	111,111.1	69.042	89	111,699.0	69.407
45	111,130.9	69.054	90	111,699.3	69.407

* From S. S. Gannett, *Geographic Tables and Formulas, U.S. Geological Survey Bulletin 650.*

† These quantities express the number of meters and statute miles contained within an arc of which the degree of latitude named is the middle; thus, the quantity 111,032.7, opposite latitude 40°, is the number of meters between latitude 39° 30′ and latitude 40° 30′.

TABLE II

Lengths of Degrees of the Parallel

(Extracted from Appendix No. 6, *U.S. Coast and Geodetic Survey Report* for 1884.)

Latitude Degrees	Meters	Statute Miles	Latitude Degrees	Meters	Statute Miles
0	111,321	69.172	45	78,849	48.995
1	111,304	69.162	46	77,466	48.136
2	111,253	69.130	47	76,058	47.261
3	111,169	69.078	48	74,628	46.372
4	111,051	69.005	49	73,174	45.469
5	110,900	68.911	50	71,698	44.552
6	110,715	68.795	51	70,200	43.621
7	110,497	68.660	52	68,680	42.676
8	110,245	68.504	53	67,140	41.719
9	109,959	68.326	54	65,578	40.749
10	109,641	68.129	55	63,996	39.766
11	109,289	67.910	56	62,395	38.771
12	108,904	67.670	57	60,774	37.764
13	108,486	67.410	58	59,135	36.745
14	108,036	67.131	59	57,478	35.716
15	107,553	66.830	60	55,802	34.674
16	107,036	66.510	61	54,110	33.623
17	106,487	66.169	62	52,400	32.560
18	105,906	65.808	63	50,675	31.488
19	105,294	65.427	64	48,934	30.406
20	104,649	65.026	65	47,177	29.315
21	103,972	64.606	66	45,407	28.215
22	103,264	64.166	67	43,622	27.106
23	102,524	63.706	68	41,823	25.988
24	101,754	63.228	69	40,012	24.862
25	100,952	62.729	70	38,188	23.729
26	100,119	62.212	71	36,353	22,589
27	99,257	61.676	72	34,506	21.441
28	98,364	61.122	73	32,648	20.287
29	97,441	60.548	74	30,781	19.127
30	96,488	59.956	75	28,903	17.960
31	95,506	59.345	76	27,017	16.788
32	94,495	58.716	77	25,123	15.611
33	93,455	58.071	78	23,220	14.428
34	92,387	57.407	79	21,311	13.242
35	91,290	56.725	80	19,394	12.051
36	90,166	56.027	81	17,472	10.857
37	89,014	55.311	82	15,545	9.659
38	87,835	54.579	83	13,612	8.458
39	86,629	53.829	84	11,675	7.255
40	85,396	53.063	85	9,735	6.049
41	84,137	52.281	86	7,792	4.842
42	82,853	51.483	87	5,846	3.632
43	81,543	50.669	88	3,898	2.422
44	80,208	49.840	89	1,949	1.211
45	78,849	48.995	90	0	0.000

TABLE III

Co-ordinates of Curvature

Natural scale—Values of X and Y in meters

Longi-tude	Latitude 24° X	Latitude 24° Y	Longi-tude	Latitude 25° X	Latitude 25° Y	Longi-tude	Latitude 26° X	Latitude 26° Y
° ′			° ′			° ′		
1 00	101,753	361	1 00	100,951	372	1 00	100,118	383
2 00	203,500	1,449	2 00	201,896	1,489	2 00	200,231	1,532
3 00	305,237	3,250	3 00	302,831	3,351	3 00	300,332	3,447
4 00	406,959	5,778	4 00	403,749	5,957	4 00	400,416	6,128
5 00	508,660	9,028	5 00	504,645	9,307	5 00	500,476	9,574
6 00	610,336	13,001	6 00	605,514	13,401	6 00	600,506	13,786
7 00	711,981	17,695	7 00	706,349	18,239	7 00	700,501	18,763
8 00	813,590	23,109	8 00	807,146	23,821	8 00	800,456	24,505
9 00	915,159	29,245	9 00	907,899	30,146	9 00	900,364	31,011
10 00	1,016,681	36,102	10 00	1,008,603	37,215	10 00	1,000,218	38,282
11 00	1,118,152	43,679	11 00	1,109,252	45,026	11 00	1,100,015	46,316
12 00	1,219,566	51,977	12 00	1,209,841	53,578	12 00	1,199,747	55,114
13 00	1,320,919	60,994	13 00	1,310,364	62,873	13 00	1,299,409	64,675
14 00	1,422,205	70,731	14 00	1,410,815	72,909	14 00	1,398,994	74,998
15 00	1,523,420	81,186	15 00	1,511,190	83,685	15 00	1,498,498	86,082
16 00	1,624,558	92,360	16 00	1,611,483	95,202	16 00	1,597,914	97,928
17 00	1,725,614	104,251	17 00	1,711,688	107,458	17 00	1,697,237	110,534
18 00	1,826,583	116,859	18 00	1,811,800	120,453	18 00	1,796,460	123,899
19 00	1,927,460	130,184	19 00	1,911,813	134,186	19 00	1,895,578	138,023
20 00	2,028,240	144,225	20 00	2,011,722	148,656	20 00	1,994,585	152,905
21 00	2,128,918	158,981	21 00	2,111,522	163,862	21 00	2,093,475	168,544
22 00	2,229,488	174,451	22 00	2,211,207	179,805	22 00	2,192,243	184,939
23 00	2,329,946	190,634	23 00	2,310,771	196,482	23 00	2,290,882	202,089
24 00	2,430,287	207,530	24 00	2,410,210	213,894	24 00	2,389,387	219,993
25 00	2,530,505	225,138	25 00	2,509,518	232,038	25 00	2,487,753	238,650
26 00	2,630,596	243,458	26 00	2,608,689	250,914	26 00	2,585,973	258,061
27 00	2,730,554	262,487	27 00	2,707,718	270,521	27 00	2,684,042	278,222
28 00	2,830,374	282,225	28 00	2,806,600	290,859	28 00	2,781,953	299,132
29 00	2,930,052	302,671	29 00	2,905,329	311,925	29 00	2,879,702	320,788
30 00	3,029,582	323,825	30 00	3,003,900	333,718	30 00	2,977,281	343,197

TABLE IV

Co-ordinates of Curvature

Longitude	Latitude 27° X	Latitude 27° Y	Longitude	Latitude 28° X	Latitude 28° Y	Longitude	Latitude 29° X	Latitude 29° Y
° ′			° ′			° ′		
1 00	99,256	393	1 00	98,363	403	1 00	97,439	412
2 00	198,505	1,573	2 00	196,719	1,612	2 00	194,872	1,649
3 00	297,742	3,539	3 00	295,062	3,627	3 00	292,291	3,710
4 00	396,960	6,291	4 00	393,385	6,447	4 00	389,689	6,595
5 00	496,154	9,829	5 00	491,682	10,073	5 00	487,059	10,305
6 00	595,316	14,154	6 00	589,945	14,505	6 00	584,394	14,838
7 00	694,440	19,264	7 00	688,168	19,741	7 00	681,687	20,194
8 00	793,522	25,159	8 00	786,347	25,782	8 00	778,931	26,374
9 00	892,554	31,839	9 00	884,472	32,627	9 00	876,120	33,376
10 00	991,529	39,303	10 00	982,537	40,276	10 00	973,246	41,199
11 00	1,090,442	47,551	11 00	1,080,537	48,728	11 00	1,070,302	49,845
12 00	1,189,287	56,583	12 00	1,178,464	57,983	12 00	1,167,282	59,313
13 00	1,288,057	66,398	13 00	1,276,312	68,040	13 00	1,264,178	69,601
14 00	1,386,746	76,995	14 00	1,374,075	78,899	14 00	1,360,983	80,706
15 00	1,485,348	88,374	15 00	1,471,745	90,558	15 00	1,457,691	92,631
16 00	1,583,857	100,534	16 00	1,569,315	103,017	16 00	1,554,295	105,375
17 00	1,682,267	113,474	17 00	1,666,781	116,275	17 00	1,650,787	118,935
18 00	1,780,570	127,193	18 00	1,764,135	130,331	18 00	1,747,161	133,311
19 00	1,878,762	141,690	19 00	1,861,371	145,185	19 00	1,843,410	148,502
20 00	1,976,836	156,966	20 00	1,958,481	160,835	20 00	1,939,527	164,506
21 00	2,074,786	173,018	21 00	2,055,460	177,280	21 00	2,035,505	181,324
22 00	2,172,606	189,845	22 00	2,152,302	194,518	22 00	2,131,338	198,953
23 00	2,270,289	207,447	23 00	2,248,998	212,550	23 00	2,227,020	217,392
24 00	2,367,830	225,823	24 00	2,345,544	231,374	24 00	2,322,539	236,640
25 00	2,465,222	244,970	25 00	2,441,932	250,988	25 00	2,417,893	256,695
26 00	2,562,459	264,889	26 00	2,538,156	271,391	26 00	2,513,074	277,558
27 00	2,659,535	285,577	27 00	2,634,210	292,582	27 00	2,608,075	299,224
28 00	2,756,445	307,035	28 00	2,730,087	314,559	28 00	2,702,890	321,694
29 00	2,853,181	329,259	29 00	2,825,779	337,321	29 00	2,797,511	344,964
30 00	2,949,739	352,249	30 00	2,921,284	360,866	30 00	2,891,931	369,036

TABLE V

Co-ordinates of Curvature

	Latitude 30°			Latitude 31°			Latitude 32°	
Longitude	*X*	*Y*	Longitude	*X*	*Y*	Longitude	*X*	*Y*
° ′			° ′			° ′		
1 00	96,487	421	1 00	95,505	429	1 00	94,494	437
2 00	192,967	1,684	2 00	191,002	1,717	2 00	188,980	1,748
3 00	289,432	3,789	3 00	286,484	3,863	3 00	283,449	3,933
4 00	385,875	6,735	4 00	381,943	6,867	4 00	377,894	6,991
5 00	482,288	10,523	5 00	477,371	10,729	5 00	472,307	10,922
6 00	578,665	15,153	6 00	572,760	15,450	6 00	566,680	15,727
7 00	674,998	20,623	7 00	668,103	21,027	7 00	661,004	21,404
8 00	771,279	26,934	8 00	763,392	27,461	8 00	755,272	27,954
9 00	867,502	34,084	9 00	858,619	34,751	9 00	849,475	35,375
10 00	963,658	42,074	10 00	953,777	42,897	10 00	943,605	43,667
11 00	1,059,741	50,903	11 00	1,048,858	51,898	11 00	1,037,655	52,829
12 00	1,155,744	60,570	12 00	1,143,854	61,753	12 00	1,131,616	62,861
13 00	1,251,658	71,074	13 00	1,238,758	72,462	13 00	1,225,480	73,761
14 00	1,347,477	82,415	14 00	1,333,561	84,024	14 00	1,319,239	85,529
15 00	1,443,193	94,591	15 00	1,428,257	96,437	15 00	1,412,885	98,164
16 00	1,538,800	107,603	16 00	1,522,837	109,701	16 00	1,506,411	111,664
17 00	1,634,290	121,449	17 00	1,617,294	123,815	17 00	1,599,808	126,029
18 00	1,729,654	136,127	18 00	1,711,621	138,777	18 00	1,693,067	141,256
19 00	1,824,887	151,637	19 00	1,805,810	154,586	19 00	1,786,182	157,346
20 00	1,919,982	167,977	20 00	1,899,852	171,241	20 00	1,879,144	174,296
21 00	2,014,930	185,147	21 00	1,993,740	188,741	21 00	1,971,946	192,105
22 00	2,109,725	203,143	22 00	2,087,468	207,085	22 00	2,064,579	210,772
23 00	2,204,359	221,966	23 00	2,181,027	226,270	23 00	2,157,035	230,295
24 00	2,298,825	241,616	24 00	2,274,411	246,295	24 00	2,249,305	250,672
25 00	2,393,116	262,089	25 00	2,367,610	267,159	25 00	2,341,385	271,901
26 00	2,487,224	283,383	26 00	2,460,618	288,860	26 00	2,433,264	293,981
27 00	2,581,144	305,498	27 00	2,553,427	311,396	27 00	2,524,935	316,910
28 00	2,674,867	328,432	28 00	2,646,029	334,765	28 00	2,616,390	340,686
29 00	2,768,385	352,183	29 00	2,738,418	358,966	29 00	2,707,621	365,307
30 00	2,861,694	376,749	30 00	2,830,585	383,997	30 00	2,798,621	390,770

TABLE VI

Co-ordinates of Curvature

Longitude ° ′	Latitude 33° X	Latitude 33° Y	Longitude ° ′	Latitude 34° X	Latitude 34° Y	Longitude ° ′	Latitude 35° X	Latitude 35° Y
1 00	93,454	444	1 00	92,385	451	1 00	91,289	457
2 00	186,899	1,777	2 00	184,762	1,803	2 00	182,568	1,828
3 00	280,328	3,997	3 00	277,121	4,057	3 00	273,830	4,112
4 00	373,731	7,106	4 00	369,454	7,212	4 00	365,064	7,310
5 00	467,100	11,102	5 00	461,751	11,268	5 00	456,261	11,421
6 00	560,428	15,986	6 00	554,004	16,225	6 00	547,412	16,445
7 00	653,704	21,757	7 00	646,205	22,082	7 00	638,509	22,381
8 00	746,922	28,414	8 00	738,344	28,839	8 00	729,542	29,229
9 00	840,072	35,957	9 00	830,413	36,494	9 00	820,501	36,987
10 00	933,146	44,385	10 00	922,403	45,048	10 00	911,379	45,656
11 00	1,026,136	53,697	11 00	1,014,305	54,499	11 00	1,002,165	55,234
12 00	1,119,033	63,893	12 00	1,106,110	64,846	12 00	1,092,850	65,721
13 00	1,211,829	74,971	13 00	1,197,809	76,089	13 00	1,183,426	77,115
14 00	1,304,515	86,931	14 00	1,289,395	88,227	14 00	1,273,884	89,415
15 00	1,397,083	99,771	15 00	1,380,858	101,258	15 00	1,364,214	102,619
16 00	1,489,526	113,491	16 00	1,472,190	115,180	16 00	1,454,407	116,728
17 00	1,581,834	128,089	17 00	1,563,381	129,993	17 00	1,544,454	131,738
18 00	1,673,998	143,564	18 00	1,654,423	145,696	18 00	1,634,347	147,650
19 00	1,766,011	159,914	19 00	1,745,308	162,287	19 00	1,724,076	164,460
20 00	1,857,866	177,138	20 00	1,836,026	179,763	20 00	1,813,632	182,168
21 00	1,949,553	195,234	21 00	1,926,569	198,124	21 00	1,903,006	200,772
22 00	2,041,062	214,201	22 00	2,016,929	217,368	22 00	1,992,190	220,268
23 00	2,132,387	234,037	23 00	2,107,097	237,493	23 00	2,081,174	240,657
24 00	2,223,521	254,740	24 00	2,197,065	258,497	24 00	2,169,949	261,936
25 00	2,314,453	276,309	25 00	2,286,823	280,378	25 00	2,258,507	284,102
26 00	2,405,175	298,741	26 00	2,376,363	303,134	26 00	2,346,838	307,154
27 00	2,495,680	322,034	27 00	2,465,677	326,763	27 00	2,434,934	331,089
28 00	2,585,961	346,187	28 00	2,554,756	351,262	28 00	2,522,787	355,905
29 00	2,676,007	371,197	29 00	2,643,591	376,629	29 00	2,610,386	381,598
30 00	2,765,812	397,061	30 00	2,732,175	402,863	30 00	2,697,724	408,168

TABLE VII

Co-ordinates of Curvature

Longitude	Latitude 36° X	Latitude 36° Y	Longitude	Latitude 37° X	Latitude 37° Y	Longitude	Latitude 38° X	Latitude 38° Y
° ′			° ′			° ′		
1 00	90,164	462	1 00	89,012	467	1 00	87,833	472
2 00	180,319	1,850	2 00	178,015	1,870	2 00	175,656	1,888
3 00	270,455	4,162	3 00	266,997	4,207	3 00	263,458	4,247
4 00	360,562	7,399	4 00	355,951	7,479	4 00	351,230	7,549
5 00	450,631	11,560	5 00	444,865	11,685	5 00	438,962	11,795
6 00	540,653	16,645	6 00	533,730	16,824	6 00	526,643	16,983
7 00	630,618	22,652	7 00	622,536	22,896	7 00	614,263	23,112
8 00	720,517	29,583	8 00	711,273	29,901	8 00	701,812	30,183
9 00	810,340	37,435	9 00	799,932	37,838	9 00	789,280	38,195
10 00	900,078	46,209	10 00	888,503	46,706	10 00	876,657	47,145
11 00	989,720	55,903	11 00	976,975	56,503	11 00	963,933	57,034
12 00	1,079,259	66,515	12 00	1,065,340	67,229	12 00	1,051,098	67,860
13 00	1,168,684	78,046	13 00	1,153,587	78,882	13 00	1,138,141	79,622
14 00	1,257,987	90,494	14 00	1,241,707	91,462	14 00	1,225,053	92,319
15 00	1,347,156	103,856	15 00	1,329,690	104,967	15 00	1,311,823	105,949
16 00	1,436,184	118,133	16 00	1,417,526	119,395	16 00	1,398,441	120,511
17 00	1,525,061	133,323	17 00	1,505,206	134,745	17 00	1,484,899	136,002
18 00	1,613,777	149,423	18 00	1,592,721	151,015	18 00	1,571,185	152,421
19 00	1,702,324	166,433	19 00	1,680,059	168,203	19 00	1,657,289	169,767
20 00	1,790,691	184,350	20 00	1,767,211	186,307	20 00	1,743,202	188,037
21 00	1,878,870	203,173	21 00	1,854,169	205,326	21 00	1,828,914	207,229
22 00	1,966,851	222,899	22 00	1,940,922	225,258	22 00	1,914,415	227,341
23 00	2,054,625	243,527	23 00	2,027,462	246,099	23 00	1,999,694	248,370
24 00	2,142,183	265,055	24 00	2,113,777	267,849	24 00	2,084,743	270,315
25 00	2,229,516	287,479	25 00	2,199,860	290,503	25 00	2,169,551	293,172
26 00	2,316,613	310,798	26 00	2,285,699	314,061	26 00	2,254,109	316,939
27 00	2,403,467	335,009	27 00	2,371,287	338,519	27 00	2,338,406	341,613
28 00	2,490,068	360,111	28 00	2,456,612	363,874	28 00	2,422,433	367,192
29 00	2,576,407	386,099	29 00	2,541,667	390,125	29 00	2,506,181	393,672
30 00	2,662,475	412,971	30 00	2,626,441	417,267	30 00	2,589,639	421,050

TABLE VIII

Co-ordinates of Curvature

	Latitude 39°			Latitude 40°			Latitude 41°	
Longitude	X	Y	Longitude	X	Y	Longitude	X	Y
° ′			° ′			° ′		
1 00	86,627	476	1 00	85,394	479	1 00	84,136	482
2 00	173,243	1,903	2 00	170,778	1,916	2 00	168,260	1,927
3 00	259,859	4,281	3 00	256,140	4,311	3 00	252,363	4,335
4 00	346,403	7,611	4 00	341,470	7,663	4 00	336,432	7,706
5 00	432,925	11,891	5 00	426,757	11,972	5 00	420,457	12,039
6 00	519,396	17,121	6 00	511,990	17,238	6 00	504,428	17,335
7 00	605,803	23,300	7 00	597,158	23,460	7 00	588,332	23,591
8 00	692,138	30,428	8 00	682,252	30,637	8 00	672,159	30,807
9 00	778,388	38,504	9 00	767,260	38,768	9 00	755,897	38,983
10 00	864,545	47,527	10 00	852,171	47,852	10 00	839,537	48,118
11 00	950,598	57,496	11 00	936,975	57,888	11 00	923,067	58,209
12 00	1,036,536	68,409	12 00	1,021,661	68,875	12 00	1,006,475	69,256
13 00	1,122,349	80,266	13 00	1,106,218	80,811	13 00	1,089,752	81,258
14 00	1,208,027	93,064	14 00	1,190,636	93,695	14 00	1,172,886	94,212
15 00	1,293,559	106,802	15 00	1,274,904	107,525	15 00	1,255,866	108,117
16 00	1,378,934	121,479	16 00	1,359,012	122,300	16 00	1,338,681	122,971
17 00	1,464,144	137,093	17 00	1,442,949	138,017	17 00	1,421,321	138,773
18 00	1,549,177	153,642	18 00	1,526,704	154,675	18 00	1,503,775	155,520
19 00	1,634,023	171,124	19 00	1,610,267	172,272	19 00	1,586,031	173,210
20 00	1,718,671	189,537	20 00	1,693,628	190,805	20 00	1,668,079	191,841
21 00	1,803,113	208,878	21 00	1,776,775	210,272	21 00	1,749,909	211,409
22 00	1,887,337	229,146	22 00	1,859,698	230,671	22 00	1,831,509	231,914
23 00	1,971,333	250,337	23 00	1,942,387	251,998	23 00	1,912,869	253,352
24 00	2,055,091	272,450	24 00	2,024,833	274,252	24 00	1,993,978	275,719
25 00	2,138,602	295,481	25 00	2,107,023	297,430	25 00	2,074,826	299,014
26 00	2,221,854	319,429	26 00	2,188,948	321,528	26 00	2,155,402	323,233
27 00	2,304,838	344,289	27 00	2,270,597	346,543	27 00	2,235,695	348,374
28 00	2,387,545	370,059	28 00	2,351,961	372,473	28 00	2,315,695	374,432
29 00	2,469,963	396,736	29 00	2,433,029	399,314	29 00	2,395,392	401,404
30 00	2,552,084	424,317	30 00	2,513,790	427,063	30 00	2,474,774	429,287

TABLE IX

Co-ordinates of Curvature

Longitude	Latitude 42° X	Latitude 42° Y	Longitude	Latitude 43° X	Latitude 43° Y	Longitude	Latitude 44° X	Latitude 44° Y
° ′			° ′			° ′		
1 00	82,851	484	1 00	81,541	485	1 00	80,206	486
2 00	165,691	1,935	2 00	163,071	1,941	2 00	160,401	1,945
3 00	248,508	4,354	3 00	244,578	4,367	3 00	240,572	4,375
4 00	331,292	7,739	4 00	326,050	7,763	4 00	320,708	7,778
5 00	414,030	12,092	5 00	407,476	12,129	5 00	400,797	12,152
6 00	496,712	17,410	6 00	488,844	17,464	6 00	480,827	17,496
7 00	579,325	23,693	7 00	570,143	23,766	7 00	560,786	23,811
8 00	661,861	30,941	8 00	651,361	31,036	8 00	640,662	31,094
9 00	744,305	39,152	9 00	732,486	39,272	9 00	720,445	39,345
10 00	826,648	48,325	10 00	813,508	48,474	10 00	800,122	48,563
11 00	908,879	58,459	11 00	894,415	58,639	11 00	879,681	58,746
12 00	990,985	69,553	12 00	975,195	69,766	12 00	959,110	69,893
13 00	1,072,956	81,605	13 00	1,055,837	81,854	13 00	1,038,399	82,002
14 00	1,154,781	94,614	14 00	1,136,329	94,901	14 00	1,117,535	95,072
15 00	1,236,449	108,577	15 00	1,216,661	108,905	15 00	1,196,507	109,100
16 00	1,317,948	123,493	16 00	1,296,820	123,864	16 00	1,275,303	124,084
17 00	1,399,267	139,360	17 00	1,376,795	139,777	17 00	1,353,911	140,023
18 00	1,480,395	156,175	18 00	1,456,575	156,640	18 00	1,432,320	156,913
19 00	1,561,321	173,937	19 00	1,536,148	174,451	19 00	1,510,519	174,753
20 00	1,642,035	192,642	20 00	1,615,505	193,209	20 00	1,588,496	193,540
21 00	1,722,524	212,289	21 00	1,694,632	212,909	21 00	1,666,240	213,270
22 00	1,802,779	232,874	22 00	1,773,519	233,551	22 00	1,743,738	233,942
23 00	1,882,788	254,396	23 00	1,852,155	255,129	23 00	1,820,980	255,552
24 00	1,962,540	276,850	24 00	1,930,528	277,642	24 00	1,897,955	278,096
25 00	2,042,024	300,234	25 00	2,008,628	301,087	25 00	1,974,650	301,572
26 00	2,121,230	324,544	26 00	2,086,443	325,459	26 00	2,051,055	325,977
27 00	2,200,146	349,778	27 00	2,163,963	350,750	27 00	2,127,159	351,306
28 00	2,278,762	375,932	28 00	2,241,176	376,974	28 00	2,202,950	377,555
29 00	2,357,067	403,002	29 00	2,318,071	404,109	29 00	2,278,417	404,722
30 00	2,435,052	430,985	30 00	2,394,639	432,157	30 00	2,353,550	432,801

TABLE X

Co-ordinates of Curvature

Longitude ° ′	Latitude 45° X	Latitude 45° Y	Longitude ° ′	Latitude 46° X	Latitude 46° Y	Longitude ° ′	Latitude 47° X	Latitude 47° Y
1 00	78,847	486	1 00	77,464	486	1 00	76,056	485
2 00	157,682	1,946	2 00	154,915	1,945	2 00	152,100	1,942
3 00	236,493	4,378	3 00	232,342	4,376	3 00	228,119	4,368
4 00	315,269	7,783	4 00	309,732	7,779	4 00	304,101	7,765
5 00	393,996	12,160	5 00	387,074	12,153	5 00	380,034	12,131
6 00	472,663	17,508	6 00	464,354	17,498	6 00	455,904	17,467
7 00	551,258	23,826	7 00	541,562	23,813	7 00	531,700	23,770
8 00	629,769	31,114	8 00	618,684	31,096	8 00	607,410	31,040
9 00	708,184	39,370	9 00	695,708	39,347	9 00	683,020	39,276
10 00	786,492	48,594	10 00	772,623	48,565	10 00	758,520	48,477
11 00	864,679	58,782	11 00	849,416	58,747	11 00	833,895	58,640
12 00	942,735	69,936	12 00	926,075	69,893	12 00	909,135	69,765
13 00	1,020,647	82,051	13 00	1,002,588	82,000	13 00	984,227	81,849
14 00	1,098,404	95,127	14 00	1,078,943	95,067	14 00	1,059,158	94,890
15 00	1,175,994	109,162	15 00	1,155,128	109,091	15 00	1,133,917	108,887
16 00	1,253,404	124,153	16 00	1,231,131	124,071	16 00	1,208,491	123,837
17 00	1,330,624	140,099	17 00	1,306,940	140,003	17 00	1,282,868	139,738
18 00	1,407,640	156,996	18 00	1,382,543	156,887	18 00	1,357,036	156,587
19 00	1,484,443	174,842	19 00	1,457,928	174,718	19 00	1,430,984	174,381
20 00	1,561,019	193,635	20 00	1,533,083	193,494	20 00	1,504,697	193,118
21 00	1,637,358	213,371	21 00	1,607,997	213,212	21 00	1,578,166	212,793
22 00	1,713,447	234,048	22 00	1,682,657	233,869	22 00	1,651,377	233,405
23 00	1,789,276	255,663	23 00	1,757,052	255,462	23 00	1,724,320	254,950
24 00	1,864,831	278,211	24 00	1,831,170	277,987	24 00	1,796,982	277,425
25 00	1,940,103	301,690	25 00	1,904,999	301,441	25 00	1,869,351	300,824
26 00	2,015,079	326,097	26 00	1,978,528	325,820	26 00	1,941,415	325,146
27 00	2,089,749	351,427	27 00	2,051,745	351,120	27 00	2,013,163	350,386
28 00	2,164,100	377,676	28 00	2,124,639	377,337	28 00	2,084,583	376,539
29 00	2,238,121	404,841	29 00	2,197,197	404,468	29 00	2,155,663	403,602
30 00	2,311,802	432,918	30 00	2,269,410	432,507	30 00	2,226,392	431,569

TABLE XI

Co-ordinates of Curvature

Longitude	Latitude 48° X	Latitude 48° Y	Longitude	Latitude 49° X	Latitude 49° Y	Longitude	Latitude 50° X	Latitude 50° Y
° ′			° ′			° ′		
1 00	74,626	484	1 00	73,172	482	1 00	71,696	479
2 00	149,239	1,936	2 00	146,331	1,928	2 00	143,379	1,917
3 00	223,827	4,355	3 00	219,465	4,337	3 00	215,037	4,313
4 00	298,377	7,742	4 00	292,561	7,709	4 00	286,656	7,667
5 00	372,877	12,095	5 00	365,606	12,044	5 00	358,224	11,978
6 00	447,314	17,414	6 00	438,588	17,340	6 00	429,727	17,246
7 00	521,677	23,698	7 00	511,493	23,598	7 00	501,154	23,469
8 00	595,951	30,946	8 00	584,310	30,815	8 00	572,492	30,646
9 00	670,125	39,157	9 00	657,026	38,991	9 00	643,727	38,777
10 00	744,186	48,329	10 00	729,627	48,123	10 00	714,847	47,859
11 00	818,123	58,461	11 00	802,102	58,212	11 00	785,839	57,891
12 00	891,921	69,552	12 00	874,438	69,254	12 00	856,691	68,872
13 00	965,570	81,598	13 00	946,622	81,248	13 00	927,389	80,798
14 00	1,039,056	94,598	14 00	1,018,642	94,191	14 00	997,922	93,669
15 00	1,112,367	108,551	15 00	1,090,485	108,082	15 00	1,068,277	107,482
16 00	1,185,491	123,453	16 00	1,162,138	122,918	16 00	1,138,440	122,234
17 00	1,258,416	139,302	17 00	1,233,591	138,697	17 00	1,208,400	137,923
18 00	1,331,129	156,096	18 00	1,304,829	155,416	18 00	1,278,144	154,546
19 00	1,403,618	173,832	19 00	1,375,840	173,071	19 00	1,347,660	172,099
20 00	1,475,871	192,506	20 00	1,446,613	191,660	20 00	1,416,934	190,581
21 00	1,547,876	212,116	21 00	1,517,135	211,180	21 00	1,485,956	209,987
22 00	1,619,620	232,658	22 00	1,587,394	231,627	22 00	1,554,711	230,314
23 00	1,691,091	254,128	23 00	1,657,378	252,998	23 00	1,623,189	251,559
24 00	1,762,279	276,524	24 00	1,727,073	275,288	24 00	1,691,377	273,717
25 00	1,833,170	299,842	25 00	1,796,470	298,495	25 00	1,759,262	296,785
26 00	1,903,752	324,077	26 00	1,865,554	322,614	26 00	1,826,833	320,758
27 00	1,974,015	349,225	27 00	1,934,315	347,640	27 00	1,894,077	345,633
28 00	2,043,945	375,283	28 00	2,002,740	373,570	28 00	1,960,983	371,404
29 00	2,113,531	402,245	29 00	2,070,817	400,399	29 00	2,027,538	398,068
30 00	2,182,762	430,107	30 00	2,138,536	428,123	30 00	2,093,731	425,619

In addition to the foregoing tables for the projection of maps, experience has shown that there arise occasions during the preparation of miscellaneous illustrations to consult other tables and other matter not always at hand. While most students will be familiar with the Greek alphabet, mathematical signs, Roman numerals, etc., the precise formation of each character is not always remembered.

The matter most often needed is given in Tables XII–XVII for convenient reference.

TABLE XII

Metric System and Equivalents

The units of linear measure most commonly used are millimeters (mm.), centimeters (cm.), decimeters (dm.), meters (m.), and kilometers (km.). 1 m. = 10 dm.; 1 dm. = 10 cm.; 1 cm. = 10 mm.; 1 km. = 1,000 meters = 0.62137 mile; 1 m. = 39.37 inches = 3.280833 feet.

Meters	Inches	Meters	Feet	Kilometers	Miles
1	39.37	1	3.280833	1	0.62137
2	78.74	2	6.561667	2	1.24274
3	118.11	3	9.842500	3	1.86411
4	157.48	4	13.123333	4	2.48548
5	196.85	5	16.404166	5	3.10685
6	236.22	6	19.685000	6	3.72822
7	275.59	7	22.965833	7	4.34959
8	314.96	8	26.246666	8	4.97096
9	354.33	9	29.527500	9	5.59233

Inches	Centimeters	Feet	Meters	Miles	Kilometers
1	2.54	1	0.304801	1	1.60935
2	5.08	2	0.609601	2	3.21869
3	7.62	3	0.914402	3	4.82804
4	10.16	4	1.219202	4	6.43739
5	12.70	5	1.524003	5	8.04674
6	15.24	6	1.828804	6	9.65608
7	17.78	7	2.133604	7	11.26543
8	20.32	8	2.438405	8	12.87478
9	22.86	9	2.743205	9	14.48412

The "vara," used in Texas, is equivalent to 33⅓ inches and is computed as representing 2.78 feet.

TABLE XIII

GEOLOGIC ERAS, PERIODS, SYSTEMS, EPOCHS, AND SERIES

Era	Period or System	Epoch or Series
Cenozoic	Quaternary	Recent
		Pleistocene ("Glacial")
	Tertiary	Pliocene
		Miocene
		Oligocene
		Eocene
Mesozoic	Cretaceous	Upper (Gulf may be used provincially)
		Lower (Comanche and Shasta may be used provincially)
	Jurassic	Upper
		Middle
		Lower
	Triassic	Upper
		Middle
		Lower
Paleozoic	Carboniferous	Permian
		Pennsylvanian (the great coal-bearing series)
		Mississippian (replaces "Lower Carboniferous")
	Devonian	Upper
		Middle
		Lower
	Silurian	
	Ordovician	Upper (Cincinnatian may be used provincially)
		Middle (Mohawkian may be used provincially)
		Lower
	Cambrian	St. Croixan (or Upper Cambrian)
		Acadian (or Middle Cambrian)
		Waucoban (or Lower Cambrian)
Proterozoic	Algonkian	Keweenawan
		Huronian
	Archean	Laurentian
		Keewatin

TABLE XIV

Partial List of Chemical Elements and Symbols

Element	Symbol	Element	Symbol	Element	Symbol
Aluminum	Al	Holmium	Ho	Rhodium	Rh
Antimony	Sb	Hydrogen	H	Rubidium	Rb
Argon	A	Indium	In	Ruthenium	Ru
Arsenic	As	Iodine	I	Samarium	Sa
Barium	Ba	Iridium	Ir	Scandium	Sc
Bismuth	Bi	Iron	Fe	Selenium	Se
Boron	B	Krypton	Kr	Silicon	Si
Bromine	Br	Lanthanum	La	Silver	Ag
Cadmium	Cd	Lead	Pb	Sodium	Na
Cæsium	Cs	Lithium	Li	Strontium	Sr
Calcium	Ca	Lutecium	Lu	Sulphur	S
Carbon	C	Magnesium	Mg	Tantalum	Ta
Cerium	Ce	Manganese	Mn	Tellurium	Te
Chlorine	Cl	Mercury	Hg	Terbium	Tb
Chromium	Cr	Molybdenum	Mo	Thallium	Tl
Cobalt	Co	Neodymium	Nd	Thorium	Th
Columbium	Cb	Neon	Ne	Thulium	Tm
Copper	Cu	Nickel	Ni	Tin	Sn
Dysprosium	Dy	Niton	Nt	Titanium	Ti
Erbium	Er	Nitrogen	N	Tungsten	W
Europium	Eu	Osmium	Os	Uranium	U
Fluorine	F	Oxygen	O	Vanadium	V
Gadolinium	Gd	Palladium	Pd	Xenon	Xe
Gallium	Ga	Phosphorus	P	Ytterbium (Neoytterbium)	Yb
Germanium	Ge	Platinum	Pt	Yttrium	Y
Glucinum	Gl	Potassium	K	Zinc	Zn
Gold	Au	Praseodymium	Pr	Zirconium	Zr
Helium	He	Radium	Ra		

TABLE XV

Greek Alphabet

Caps	Lower Case	Greek Name	English Sound	Caps	Lower Case	Greek Name	English Sound
Α	α	Alpha	A	Ν	ν	Nu	N
Β	β ϐ	Beta	B	Ξ	ξ	Xi	X
Γ	γ	Gamma	G	Ο	ο	Omicron	O short
Δ	δ	Delta	D	Π	π ϖ	Pi	P
Ε	ε	Epsilon	E short	Ρ	ρ	Rho	R
Ζ	ζ	Zeta	Z	Σ	ς σ	Sigma	S
Η	η	Eta	E long	Τ	τ	Tau	T
Θ	θ ϑ	Theta	Th	Υ	υ	Upsilon	U
Ι	ι	Iota	I	Φ	ϕ φ	Phi	F
Κ	κ	Kappa	K	Χ	χ	Chi	Ch
Λ	λ	Lambda	L	Ψ	ψ 8	Psi	Ps
Μ	μ	Mu	M	Ω	ω	Omega	O long

TABLE XVI

Roman Numerals

I	1	IX	9	LXX	70	D	500
II	2	X	10	LXXX	80	DC	600
III	3	XIX	19	XC	90	DCC	700
IV	4	XX	20	C	100	DCCC	800
V	5	XXX	30	CL	150	CM	900
VI	6	XL	40	CC	200	M	1000
VII	7	L	50	CCC	300	MD	1500
VIII	8	LX	60	CD	400	MCM	1900

TABLE XVII

Mathematical Signs

+ plus	△ triangle	∽ difference	∴ therefore
— minus	○ circle	∫ integration	∵ because
× multiplied by	∠ angle	≎ equivalence	∞ infinity
÷ divided by	∟ right angle	: ratio	∝ varies as
= equality	⊏ or > greater than	∺ geometrical proportion	√ radical
± plus or minus	⊐ or < less than	—: difference, excess	° degree
□ square	⊥ perpendicular		′ minute
▭ rectangle			″ second

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